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Improving Access to Clean Water in Rural Ecuador: The Connection Between Willingness to Pay and Population Health

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IMPROVING ACCESS TO CLEAN WATER IN RURAL ECUADOR: THE CONNECTION BETWEEN WILLINGNESS TO PAY AND POPULATION HEALTH

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List of Abbreviations and Terms

AIDS	Acquired Immune Deficiency Syndrome
CDC	Center for Disease Control and Prevention
C3	Cubic meters
DALY	Disability-Adjusted Life Years
FEPP	Fondo Ecuatoriano Populorum Progressio-Grupo Social FEPP
GBD	Global Burden of Disease
GDP	Gross Domestic Profit
GHG	Greenhouse Gas
HIV	Human Immunodeficiency Virus Infection
IBD	Inter-American Development Bank
IHME	Institute for Health Metrics and Evaluation
IRB	Institutional Review Board
JMP	Joint Monitoring Program
MoH	Ministry of Public Health
NCD	Non-communicable Diseases
NGO	Non-Governmental Organization
NTD	Neglected Tropical Diseases
OPEC	The Organization of Petroleum Exporting
SDG	Sustainable Development Goals
Ppm	Parts per million
UN	United Nations
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USD	United Stated Dollar
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WMO	World Meteorological Organization

WTP	Willingness to Pay
YLL	Years of Life Lost due to Premature Mortality
YLD	Years of Life Lost due to Disability

Terms:

Ancylostoma Duodenale	Old World Worm
Ascaris lumbricoides	Roundworm
Barrios	Towns
Bichos	Parasites
Campos	Rural Area
Canton	Sector
Intestinal nematode infection	Soil-transmitted helminths/Intestinal Worms
Necator Americanus	New World Worm
Parish	Town
Parroquia	Area
Provencia	Province
Pueblo	Town (rural)
Soil-transmitted helminths	Intestinal Worms
Systems integrals de production agro peqaria	Agribusiness production integral space
Trichuris trichiura	Whipworm

Abstract

Climate change is affecting social and environmental determinants of health through access to safe drinking water, safely managed sanitation systems, and access to health care services and the ability for individuals to break free from unsuitable circumstances. Ecological disturbances such as those caused by climate change can cause a shift in host vectors or a change in habitat that results in a greater likelihood of the pathogen coming in contact with humans. Water, sanitation, and hygiene (WASH) services and their accessibility to populations can directly impact a community's vulnerability to diseases and limiting factors to increase economic growth. If rural communities in Ecuador gained access to safe water services their healthy life years would be improved compared to those accessing unsafe water by reducing the burden of a water-related disease. The intended outcomes of this project are to establish a willingness to pay (WTP) price that represents how much rural Ecuadorian communities are willing and able to pay for access to safe water services and to quantify how one's healthy life years are affected. Lastly, this research speaks to the larger global correlation between WASH and climate change. As the range of climate change impact expands in intensity and frequency this directly impacts water and sanitation infrastructure, the quality and quantity of water sources and heightens favorable conditions for pathogens of communicable disease growth and reproduction increasing their rate of human infection and suitable environments. Measures that mitigate the risks of diseases include the implementation of safe and effective sanitation systems and drainage such as, construction, reforestation, expanded access to safe drinking water services and development of healthcare services with increased hygiene practices.

Introduction

Water, sanitation, and health (WASH) are inextricably linked to the effects of climate change. Globally, natural disasters, floods and droughts can cause health repercussions linked to water (WHO, 2018a). The lack of adequate water and sanitation services have resulted in thousands of lives lost to disease and morbidity worldwide due to exposure and contamination of water but have exacerbated conditions of poverty and unsuitable environments due to the impacts of climate change (WHO, 2018a). Climate change has also facilitated relationships between changing environments and some infectious disease vectors such as parasitic infections from widening their range, increasing mobility and reproduction cycles, accessibility of contact with humans and intensifying outbreaks due to favorable environmental factors (Hunter, 2003; Anderson et al., 1993). Water is at the heart of climate change impacts due to increased natural disasters ability to destroy water and sanitation systems leaving behind partial or unsalvageable systems filled with contained water and sewage run-off that can quickly foster conditions for parasitic growth and disease outbreaks (Hunter, 2003; Anderson et al., 1993). As water continues to be altered by climate change, human populations are faced with new circumstances of water shortages, contact with unsafe water and sanitation systems and the overuse and dependence on fragile ecosystems are linked directly to natural economies. As a result, quantities and quality of water resources and people's use of water services is directly linked to a countries economy (Stern, 2014; Stevenson et al., 2012).

Globally, around two million people die every year due to diarrheal disease with 80% of those cases in children under the age of five (WHO and WMO, 2012). Annually, 842,000 diarrheal deaths are a direct result of peoples use of unsafe water services which inhibit effective prevention and management for other health-related concerns stemming from their use (UNICEF

2016; WHO, 2018a, 2017b). From 2000 to 2017, current representations show seven out of ten people in 2017 used safely managed drinking water services, while eight out of ten people in rural areas still lack access to basic drinking water services, with nearly half of those living in developing countries (UNICEF and WHO, 2019). Since 2017, four out of ten people used safely managed sanitation services while seven out of ten people still lack access to basic sanitation services in rural areas (UNICEF and WHO, 2019). While over 2.1 billion people globally lack access to sufficient domestic water supplies these circumstances leave them in positions to consume less water and reserve what little amounts they have (UNICEF and WHO, 2019, 2018a, 2016c, 2016d).

Climate change affects social and environmental determinants of health through wage-earning jobs, clean air, access to safe drinking water, safely managed sanitation systems, sufficient nutritional food access, secure shelter, and access to health care services (UNICEF and WHO, 2019; WHO, 2018a, 2016e, 2016f). Human health is impacted by these changes in the environment from conditions favorable for pathogen growth, higher rates of exposure and contact to transmissive infections, rise in non-communicable and communicable disease prevalence to result in higher rates of mortality or morbidity of human populations worldwide (UNICEF and WHO, 2019; WHO, 2018a, 2018b, 2016e, 2016f). Indirect effects of climate change stem from ecological disturbances and a shortage of natural resources forcing humans to share smaller spaces with animals and unfavorable living conditions that foster growth of contaminants and decreases one's access to safely managed services such as those of water sanitation and hygiene, which consequently amplifies the range of infection and microbial growth (personal communication, K. Krepple, April 1, 2019; UNICEF and WHO, 2019; WHO, 2018a, 2018b, 2016e, 2016f). The World Health Organization (WHO) estimates that the excess risk of negative health outcomes brought about by climate change will more than double by the year 2030 (WHO, 2018a, 2016e; Pandey et al., 2014; Patz et al., 2005). Many infectious disease outbreaks occur in developing countries lead to further stress on the countries' financial situations as well as on the already scarce medical resources available. These factors will restrict countries' ability to prepare and respond to climate change events and climate-induced health externalities (WHO, 2016e, 2016f; Wu et al., 2016; UNEP, 2013; UNICEF, 2005). In addition, countries which face the highest burden of climate-sensitive diseases are also regions with the lowest per capita greenhouse gas emissions (GHG), and they have the lowest capacity to adapt to these changes in the future (WHO, 2017; Pandey et al., 2014; Patz et al., 2005; UNICEF, 2005; Winder & Schindler, 2004; Rodó et al., 2000). Therefore, it is imminent to address the issues of inadequate WASH services to enable communities a chance of healthier livelihoods in changing environments that will only become less favorable for vulnerable human populations.

Problem Statement

How has unclean water cost the community physically, socially, and economically in rural Ecuador and what are the benefits to develop improved water and sanitation systems?

Inadequate WASH services provide various transmission routes through contaminated water and untreated fecal matter contaminants that foster increased microbiological production and presence in water sources (Prüss-Üstün et al., 2004). Microscopic parasites found in these environments can infect humans via drinking water and other water-related activities, contact with infected soil near sanitation systems, contaminated food, or direct transmission through contact with infected hosts (King, 2015; Hunter, 2003; Anderson et al., 1993; CDC, n.d.). In addition, transmission can originate from reduced personal, domestic and agricultural practices which include the lack of personal hygiene (King, 2015; Prüss-Üstün et al., 2004; Hunter, 2003;

Anderson et al., 1993). Another source of infections stems from water storage in households that can become a host for microbial activity and growth. Even if the original source of water was free of contaminants, if the collector's hands are not free from contaminants or if someone (a child) comes into contact with the bucket after playing outside near animals, latrines, or contaminated soil and their hands are not clean the water bucket will soon become infected with microscopic bacteria that will grow within days, contaminating the water.

1.0 Background

While climate change bears a burden of catastrophe, indisposition and impairments to both ecosystems and human populations arguably one of the most threatening effects of climate change is the rise of infectious disease. The WHO estimates that 150,000 lives have been lost annually in the last 30 years due to climate changes largely arising from anthropogenic causes (WHO, 2016d, 2016e). Recent research has found that several infectious diseases will continue to thrive in environments now showing long-term climate warming trends. With an increase in temperatures that amplify extreme weather events, outbreaks of diseases will occur in non-traditional places (Altizer et al., 2013; Cockburn and Cassanos, 1960; Lipp et al., 2002; Wu et al., 2016). In developing countries, the WHO estimated in 2014, 3.4 million people died from water-related diseases (WHO, 2017). Measures that mitigate the risks of diseases include the implementation of safe and effective sanitation systems and drainage such as, construction, reforestation, expanded access to safe drinking water services and development of healthcare services with increased hygiene practices (WHO, 2018a, 2016e; UNEP, 2013; UNICEF, 2005; Wu et al., 2016).

1.1 Origin of Study

This capstone project and paper took place in Ecuador, a country in the western hemisphere of South America which borders the Pacific Ocean and sits between Colombia and Peru (CIA, 2019). Ecuador is known for its diversity in climatic zones and the array of geographical systems found within its borders. Ecuador has four different distinct regions ranging from the Orient/Amazon rainforest, Sierra/Andes, Coast/Costa and the Galapagos Islands (CIA, 2019). The Orient is described as the tropical rainforest in the Amazon's upper tributaries, the high Andean mountains also referred to as the Sierra is situated at the world's equatorial bulge naming Chimborazo Mountain the highest point on the planet from earth's crust sitting at an elevation of 6,267 meters (18,801 ft) (CIA, 2019). Positioned westward from the Andes becomes the Coastal region which includes dry tropical forests on the Pacific coast dropping to sea level altitude. Lastly, Ecuador's furthest point in the Pacific and climatic zone is the Insular Galapagos Islands known for its World Heritage site status and ecosystem diversity (UNDP, n.d.). In 2018 Ecuador documented a population of 16.5 million people with a low population's growth of 1.25% (INEC, 2010). Almost half the country's population is concentrated in the interior of the Andean mountains' basins and valleys along with a large population who reside in the western coastal region. The Orient and northeastern-most point of Ecuador within the Amazon Basin remain thinly populated (CIA, 2019). While Spanish is the official language of Ecuador, Quechua and Shuar are also recognized as official languages of intercultural relations along with other used by people in the different regions. The total area of Ecuador is an estimated 283,561 square kilometers, roughly smaller than the size of Nevada state, USA (CIA, 2019). Figure 1 below highlights Ecuador's geographical position within South

America along with distinguishing the country's four regions along with highlighted points of the two regions included in my study.

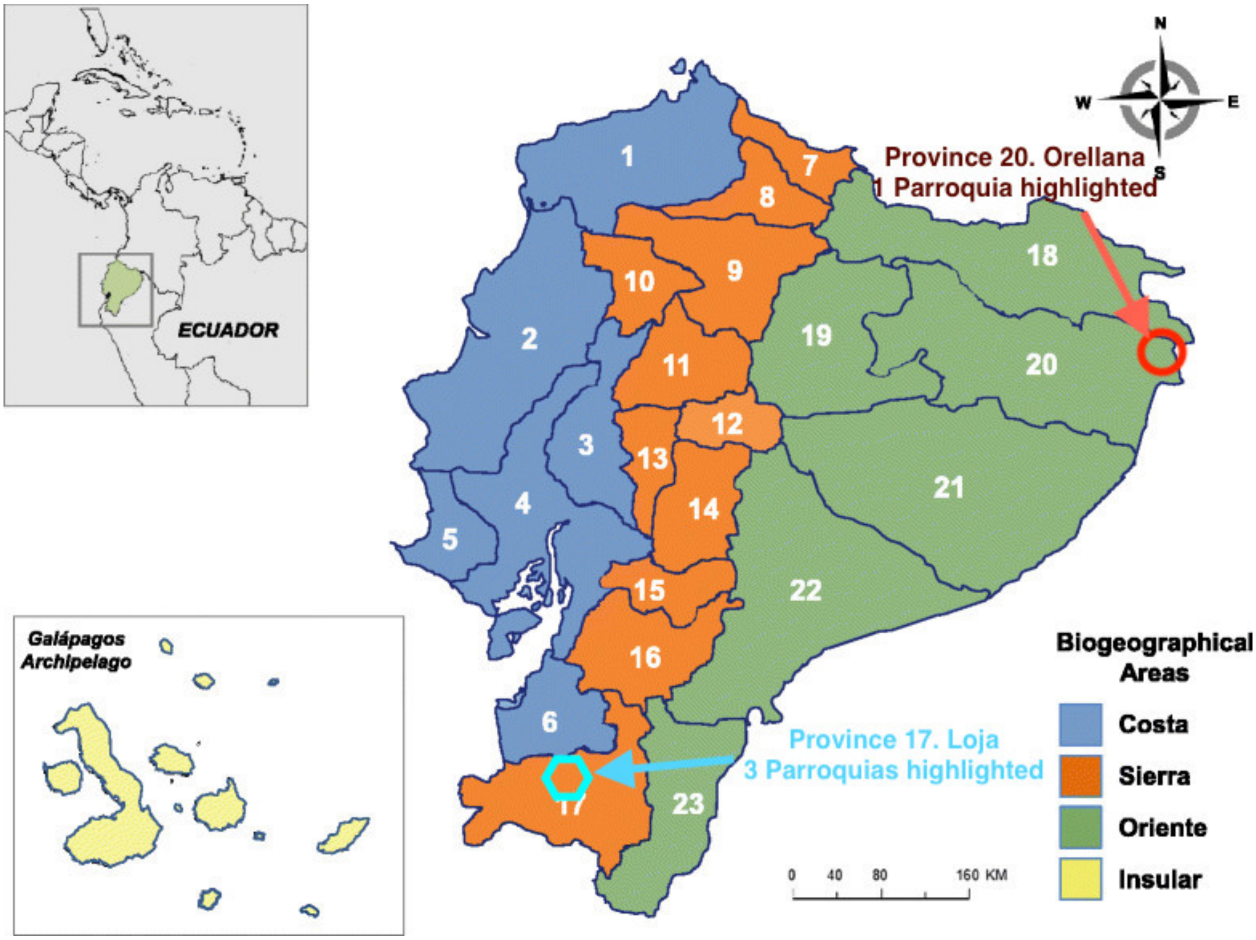


Figure 1. Map of Ecuador and Project Sites
(Adapted from Brito and Borges 2015:3, Figure 2, access July 24, 2019)

1.2 Provinces Under Study

Over the course of three months communities within two regions of Ecuador, the Amazon and Sierra, were studied to explore at large rural populations access to WASH services and in what capacity could communities identify health consequences related to their use of unsafe water, regions vulnerability and water-related stress due to climate change and the presence of impacts of climate change on parasitic infections. My research was supported by WaterStep, an NGO focused on international WASH development to respond to critical needs for safe water through evaluation and implementation of water purification systems and training on these systems use and WASH education. Research under this organization provided some of the first steps to understand real-time water circumstances in rural communities to determine social and economic variables attached to a community's willingness to pay (WTP) for access to safe water services and pre-safe water project health assessments. These communities studied were in a variety of stages in their progress to gain sustainable access to safe water systems for all, a goal not only for Ecuador but also for the UN Sustainable Development Goals (UN, 2016).

Situated in the Amazonia rainforest, the north-central region of Ecuador, "*Provincia de* Orellana" (Orellana Province) is one of the newest provinces of the country. With a population of 136,396 people most of the Indigenous groups Warrant, Schuar and *Kichwa* nationalities, this region has rich biodiversity and is claimed as one of the world's most biodiverse regions and declared by UNESCO as a Biosphere Reserve (CIA, 2019). The Napo River Basin is considered one of the most important in the Amazon region and in the country due to the numerous communities that have settled on the river banks to use the river for natural resources and the primary mode of transportation within the Amazon. The Province of Orellana has an area of around 21,675 square kilometers, including 6 provinces and shares the main river bodies with Peru's Amazon (CIA, 2019). Fieldwork in the Orellana Province was completed in "*Comuna Kichwua* Alta Florencia, *Parroquia* Nuevo Rocafuerte, *Canton* Aguarico", commonly known as Alta Florencia community. This area is also known for gold and oil extraction which is one of the main economies of Ecuador. Alta Florencia, a community of 22 families depend on the biodiversity of its habitat for resources but in 2013, a landslide ruptured an oil pipeline in the Ecuadorean Amazon which leaked around 11,000 barrels of oil (420,000 gallons) into the Coca River. This river connects to the larger Napo River which borders Yasuní National Park, leading into Peru and Brazil's Amazon (Hance, 2013). The pipeline operator Petroecuador claimed responsibility for this incident and hired the U.S. Clean Caribbean and America's Company to handle the cleanup. The repercussion of this spill temporarily and long-term contaminated water used by 80,000 residents of the Puerto Francisco de Orellana *Provencia* (Province). In addition to environmental damages to community's water resources, ecologically this spill occurred in one of the world's most biodiverse regions, an area now overrun by oil production from both national and international companies (Hance, 2013). In response to the river contamination, the U.S. Clean Caribbean and America's Company provided each household in the affected communities one 500-gallon rainwater tank to use instead of the oil-contaminated river water. Tanks were only given to those currently living in the community and did not account for new families moving in or the size of families and their water needs. The effects of this spill and the rainwater tanks were given to community members will be discussed in detail in my study and results. Figure 2 below display the Orellana Province within the Orient region and the marked black circle and zoomed-in red pin signifies approximately, where my research in this region was completed.

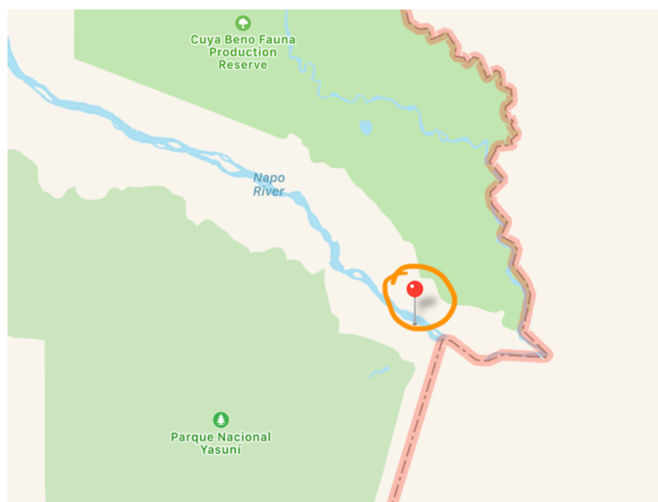


Figure 2. Map of Orellana Province (left) and Alta Florencia Community (right)
(Adapted from Ecuador World Headquarters, 2016 and GoogleEarth, access July 6, 2019)

The second study area found in the southern Sierra region of Ecuador in the Andean mountains was located in "Loja *Provencia*, *Canton* Loja". With a population of around 448,966 in 2010 and an area of 10,995 square kilometers this area is situated in the bisect of the country between the humid Amazon

Basin and Peru's border, making it the cloud forest biome of the region (CIA, 2019; Population Statistics…, 2014). There are 16 *Cantons* in the Province of Loja and my research was conducted in the *Cantons* Puyango and Pindal. The *parroquia* (area) of Alamor, El Arenal and Chaquinal comprise of *barrios* (communities/ neighborhoods) of which 14 communities were included in this study. Figure 3 below provides detail on the different *cantons* of Loja Province along with highlighting the three *parroquia's* (areas) included in my research. Marked green is the El Arenal *parroquia*, orange represents Alamor *parroquia* and red marks Chaquinal *parroquia*. An additional enlarged figure 4, adapted from GoogleEarth labels the three *parroquia's*.

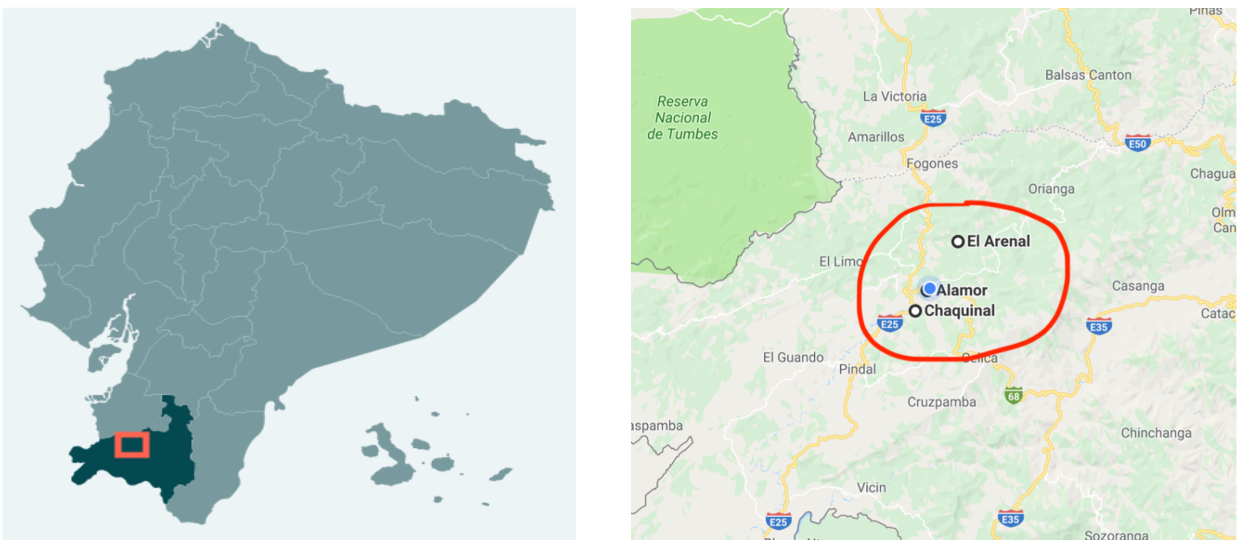


Figure 3. Map of Loja Province (left) and Three *Parroquia*s (right)
(Adapted from Ecuador World Headquarters, 2016 and GoogleEarth, access July 6, 2019)

2.0 Literature Review

The WHO partnered with the World Meteorological Organization (WMO) to understand the impacts of climate change on global populations in terms of water security, economies, vulnerability, individual country risk and the spread or intensification of infectious diseases (WHO and WMO, 2012). Annually natural weather disasters trigger environmental and economic crises leading to human death and displacement, destruction of social and economic infrastructure and additional destruction of ecosystems and natural resources (WHO and WMO, 2012). In 2011, 332 natural disasters were recorded ranging from natural hazards in 101 countries causing more than 30,770 deaths which affected over 244 million people (WHO and WMO, 2012). In the last 10 years, 80-90% of all-natural disasters have stemmed from floods, droughts, tropical cyclones, heatwaves and severe storms (WHO, 2018b; WHO and WMO, 2012). While the impact of these natural events can be documented by cases of mortality and country GDP damages, not presented statistically is the entire impact climate-induced weather events have caused in terms of morbidity, trauma and post-disaster distress, and displacement of entire populations (Stevenson et al., 2012; Ennis-McMillan, 2001). Natural disasters cause millions of people to suffer injury, vulnerability to infectious disease outbreaks, long-term disabilities as well as emotional distress and relived memories of lost lives and the disaster event (Stevenson et al., 2012; WHO and WMO, 2012; Ennis-McMillan, 2001). Since 1960, reports of extreme weather events have more than tripled in occurrence and severity which scientists have attributed to the effects of climate change in many regions of the world (Taye et al., 2018; Stevenson et al., 2012). The increase in natural disasters has impacted a broader range of people due to population increases and over the last 30 years there has been a 114% increase in populations that live in flood-prone river basins and those in cyclone-exposed coastlines has grown by 192% globally (WHO and WMO, 2012; Webb and Iskandarani, 1998). As the world becomes inhabited by more people and natural resources become more vulnerable to impacts from weather events and anthropogenic climate change this has resulted in human settlements alongside waterways to gain better access to resources. In addition, creating an increase in informal settlements where populations set up temporary structures usually lacking WASH services and living in areas unsuitable for permanent development (Taye et al., 2018; Webb and

Iskandarani, 1998). The world is currently witnessing drastic changes to water resources and there is increased evidence which correlates an increase in violence and conflict over access to food and water resources (WHO and WMO, 2012; Webb and Iskandarani, 1998). In 2050, an estimated 4.8 to 5.7 billion people will live in water-scarce areas at least one month a year (Taye et al., 2018).

2.1 Water Insecurity

Water insecurity concerns availability, access, use of freshwater, and its services (Stevenson et al., 2012). The supply of available water is largely dependent on ecological factors and anthropogenic influences. "Distribution" of water is explained as the amount of water humans can use for livelihood activities and consumption. Water "security" refers directly to the quantity of water based on its location and availability (Motlaleng and Thukuza, 2011; Stevenson et al., 2012; Taye et al., 2011; Webb and Iskandarani, 1998). Water "access" refers to household control of water as a commodity which can be influenced by modes of distribution based on national policies and investment priorities. Access to water is often dependent on an individual's income, physical location, and in some cases, status (Motlaleng and Thukuza, 2011; Tussupova et al, 2015; Webb and Iskandarani, 1998).

Approximately one-third of the world's population lives in countries that experience moderate to high water stress, and around 1.1 billion people currently lack access to safe drinking water (Stern, 2014). Access, adequacy, and lifestyle have been outlined as the three dimensions to water insecurity (Stevenson et al., 2012). Worldwide 884 million people drink water from unimproved sources due to at least one dimension of water insecurity in their lives (WHO, 2018a, 2016c). This has led to disparities in the availability of safe water to public health (Stevenson et al., 2012). Due to the collection of freshwater sources usually further away from households, women are usually given this task, which means time, and effort expended on the collection of water has constrained women from participating in income-generated activities, which contributes to impoverishment and stresses such as malnutrition and dehydration (Ennis-McMillan, 2001; Taye et al., 2018; UNICEF, 2016; Wutich, 2009). The WHO estimated that a quantity of 20 liters of clean potable water per capita per day should address basic hygiene and cooking requirements, but in many developing countries, this is far from realistic quantities accessible for families (WHO, 2016a; Ennis-McMillan, 2001). Additional water should be used for bathing, laundry and additional water-related activities (WHO, 2016a).

In addition to water security concerns, billions of people globally live without access to even the most basic sanitation services (WHO, 2018b). Those who have access to proper sanitation services decrease their risk of contracting diarrheal illnesses, parasitic diseases such as intestinal worms, schistosomiasis, trachoma along with other infectious diseases (WHO, 2018a). Poor sanitation and contaminated water directly impact one's ability to live a long healthy life in which they are able to attain wage-earning jobs, live disease-free, and maintain a healthy and balanced physical and physiological existence. The effects non-access to proper water and sanitation services are felt by roughly 2.6 billion people in developing countries that invest large sums of their household time and income in attempts to secure access to safe drinking water and proper sanitation services if permittable (WHO, 2018a; Bartram, 2008).

Improvements to WASH and projects to develop these systems have gained attention by the majority of countries who actively comply to the 2030 Sustainable Development Goals (SDG). SDG Agenda 2030 ensures all United Nation (UN) member states "commit to taking transformative steps to shift a world onto a sustainable and resilient path by seeking to realize the rights all humans are entitled to…" (UN, 2018, n.d.). The need to ensure availability and sustainable management of water and sanitation services for all include targets for universal access to safe drinking water should be a top priority for countries who have populations unable to access these services on a baseline level (UN, 2018; UN, n.d.). Populations unable to use these basic services have suffered greatly in their healthy life years based on to one's ability to achieve a healthy life, gain economic growth to break free from unsuitable circumstances, poverty holds and not succumb to diseases derived from exposure to unsafe water and safe sanitation services.

2.2 Economics' of Ecuador

Ecuador experienced economic growth from the years 2008 to 2014 with an average annual increase of 4.6% in gross domestic profits (GDP) (PAHO, n.d.). This growth can be attributed to their high oil prices, external financing flows and improved tax collection but this growth hit a stark slowdown in late 2014 from a decline in global oil prices, their difficultly to access new financial sources and the appreciation of the United States dollar ($ USD) which was adopted by Ecuador in 2000 (PAHO, n.d.). In correlation with economic slowdowns, from 2008 to 2014 the period of Ecuador's economic growth the Gini coefficient, a statistical representation of income and wealth distributions of countries residents fell from 0.54 to 0.47 (PAHO, n.d.). This can be attributed to Ecuador's efforts to reduce poverty in all forms with a specific focus on rural development which shown successfully as of 2015 poverty rates declined 16.5% (PAHO, n.d.). Once the economy started to slow down in 2014 poverty rates slightly increased as a total average but in rural populations, there was a larger increase along with higher unemployment rates due to the economic slowdown (PAHO, n.d.). Ecuador has several bilateral and multilateral trade agreements giving the country total or partial tariff preference for marketing its products abroad. A large percentage of Ecuador's exports and agreements surround crude oil exports with one in specific being China's agreement. As a member of OPEC, Ecuador has shipped roundly half of its oil to Chinese firms (Ulmer, 2018). Ecuador continues to allow international and domestic oil companies into the Amazon for oil extraction which account for a third of the country's exports as of 2017 (CIA, 2019). The topic of Ecuador's dependence on Petroleum resources has raised criticism as for the lack of strict regulations for environmental damages and spills into communities and the destructions of one of the most biodiverse regions of the world.

Migration has also impacted Ecuador's economy due to the financial crisis from 2001 and 2007 over 1.6 million people were forced to leave the country in search of jobs and income (PAHO, n.d.). After the economy started to stabilize in 2008 fewer people sought international jobs while some returned to the country, but when another slowdown occurred in 2014 and 2015, there was a 20% increase in migration out of Ecuador. In addition, as of 2017, 374,879 people have immigrated into Ecuador under refugee, refugee-like situations or asylum statuses (UNHCR, 2017). The majority of refugees coming into Ecuador are from Colombia and Venezuela and either claims refugee status in Ecuador or continue through to Peru or other countries in South America (PAHO, n.d.). A rise in urbanization or those migrating to the cities in hopes for better economic opportunity and livelihoods have put increased amounts of pressure on water and sanitation services in urban spaces.

2.3 Water and Sanitation Services Access in Ecuador

Ecuador's access to reliable drinking water and sanitation services in 2015 was analyzed in the Joint Monitoring Program Report (JMP) published by the WHO and UNICEF to determine improvement and progress of populations access to services within the WASH sector. Water and sanitation services access and their quality are analyzed in terms of the standard access, safe use, and proximity to households and additional variables weighed into the classification of these services. Therefore, the WHO has defined specific classifications attributed to each WASH service. This universal standard is also followed by SDG Reports on countries who have improved access. Due to the unique categorization of these terms Appendix A provides further elaboration that will be used in the subsequent section.

Ecuador's access to drinking water sources is indicated by the percentage of the populations with access to improved water sources as defined by the WHO. In rural populations, 80.4% of the populations had access to using the least basic form of drinking water services while urban populations access to these basic services was over 99% (UNICEF and WHO, 2019; World Bank, n.d.). In the last 10 years, communities who have gained access to safely managed drinking water services within the urban sector was documented at 84.7% but only 56% of rural populations accessed these services (UNICEF and WHO, 2019; WHO, 2016c; World Bank, n.d.). As outlined by its classification this percentage represents the disproportion of rural communities who currently lack access to water services that are free from contaminants, have sufficient quantities when needed, have piped access or accessible on the premise. Nationwide the total population with access to safely managed to drink water services was 74%, but as we can see the large majority of this access was in urban spaces (UNICEF and WHO, 2019; WHO, 2016c; World Bank, n.d.). While access to drinking water services has continued steady growth there are still large populations that are accessing water services directly from water sources or continue to walk to receive water for households and this is most represented in rural populations. Thus, the correlation of rural populations rate of parasitic and diarrheal illness is greater than those using safely managed services free of contaminants.

In Ecuador as of 2015, 42.5% of the total populations had gained access to safely managed sanitation services (UNICEF and WHO, 2019; World Bank, n.d.). The percent of rural populations with access to safely managed sanitation systems was 56.6% while urban populations access to these services was only 34.4% (UNICEF and WHO, 2019; World Bank, n.d.). It is noteworthy that in 2000, 42.2% of urban populations in Ecuador had access to safely managed sanitation services and over the course of 15 years this percentage dropped by almost 8%, compared to urban populations access to water services which have shown continued growth over the last 10 years (UNICEF and WHO, 2019; World Bank, n.d.). While overall percentages of communities that practice open defecation have drastically decreased there is still a concern with the low percentage of rural populations access safely managed services and the decreased use of urban populations with this service. Water and sanitation infrastructure are key to limit the presence of communicable diseases in a community along with one's access and use of hygiene services which provide proper avenues to decrease community's exposure to diseases and harbor environments suitable for their growth and reproduction (Winder & Schindler, 2004; Lipp, Huq & Colwell, 2002). Nationwide access to basic handwashing facilities which provide soap and water in 2015 was 85.16% (World Bank, n.d.). Within urban populations access to basic handwashing, services are 90.5%, around 75.7% of rural populations access these services (World Bank, n.d.). WASH services and their access to populations can directly impact a community's vulnerability to diseases and limiting factors to increase economic growth. While Ecuador has put forth efforts for all populations to access these services climate change impacts may be experienced faster than populations can gain access and build resilience to these implications. Ecological disturbances such as those caused by climate change can cause a shift in host vectors or a change in habitat that results in a greater likelihood of the pathogen coming in contact with humans (Pandey et al., 2014; Altizer et al., 2013; Patz et al., 2005; Winder & Schindler, 2004; Lipp, Huq & Colwell, 2002; Rose et al., 2000; O'Shea & Field, 1992).

2.4 History of Climate Change Induced Events in Ecuador

Ecuador’s economy, environment, and society were greatly impacted by the 2016 earthquake that registered at a magnitude of 7.8 that killed more than 700 people and left 6,000 injured. The earthquake's epicenter was 17 miles off-shore from Manabí Province, 100 miles northwest of Quito on the coast of Ecuador (Reid, 2018). After this natural disaster, over 700,000 people required assistance and an estimated 35,000 houses were destroyed which left approximately 100,000 people in need of shelter (Reid, 2018). In addition to human costs, water, sanitation, and healthcare facilities were destroyed as a result. While Ecuador sits on the ‘Pacific Ring of Fire’ and is prone to experience frequent small earthquakes the 2016 event was the worst earthquake to strike the country since 1987 (Ulmer, 2018). Since predictions of increased natural disaster events in both frequency and intensity due to climate change, the events which occurred in Ecuador in 2016 had proven these predictions are very valuable. In early 2016 Ecuador was hit by El Niño events that caused torrential rains, mass floods and landslides that impacted many impoverished communities in Manabí Province specifically. In April 2016 the 7.8 magnitude earthquake struck which devastated regions of Ecuador. The following two months while efforts were in full force to clean up post-disaster there were several aftershocks in the regions most impacted by the earthquake, which further delayed recovery and cleanup efforts.

The aftermath of these weather events increases populations risk for disease outbreaks to flourish in times when infrastructure is damaged or non-existent, populations are living close together usually in temporary conditions and access to safe water, proper sanitation systems, and hygiene is low along with environmental damages that can leave stagnant bodies of water exposed to contaminants. These circumstances coupled with more floods onset in July spurred an outbreak of Zika (Climate Modeling…, 2018). Over 80% of reported Zika cases were in the Manabí Province which were hardest impacted by the earthquake and affected all populations displaced in shelters outside, near stagnant water bodies and lacking proper WASH infrastructure, ideal conditions for disease vectors to flourish and infect high numbers in short-ranges (Climate Modeling…, 2018; Ulmer, 2018). Seven months after the disaster, when 16,000 people still remained displaced a 5.8 magnitude earthquake hit the northwest region of Ecuador in December which led to a demand for increased humanitarian aid efforts and additional displaced populations and damaged infrastructure (Ulmer, 2018). In February 2017, almost a year after the 7.8 earthquake there was a state of emergency declared in Portoviejo, the capital of Manabí Province due to intense rains leading to severe flooding events. To exacerbate the fragile state of the Manabí Province further, in June 2017 a 6.3 magnitude earthquake struck and set the region back twofold in disaster recovery still rebuilding from the 2016 earthquake (Climate Modeling…, 2018; Ulmer, 2018) Economic damages as a result of the 2016 earthquake were estimated at $2 to $3 billion USD due to over 90% of its infrastructure destroyed in some areas (Ulmer, 2018). As shown by these continuous series of natural disaster events Ecuador suffered greatly across all environmental, societal and economic avenues. Ecuador's vulnerability for events similar to those of 2016 and 2017 are predicted to become new trends of reoccurrence in higher frequency and severity due to climate-induced factors (Norte Dame GAI, n.d.). The effect of short-term changes to environmental conditions such as floods, droughts, natural disasters, and El Niño events can be the tipping point for the effects of climate change to be sent over the edge into extreme catastrophe causing the country to take longer to recover after each event (Climate Modeling…, 2018).

2.5 Ecuador's Health System

Within the ratified 2008 Constitution, the Ministry of Public Health (MoH) holds responsibility to develop and implement the National Health Policy and all health-related activities in the country (PAHO, n.d.). The new health systems included in the 2008 Constitution also describes the three Pilar's of Healthcare and access to all within its system. This is described in the States responsibility for people's right to health, to ensure a system that is based on primary healthcare and the creation and integration of a public network of free health services (PAHO, n.d.).

Ecuador operates its healthcare from two subsystems; the public and private sector. The public sector of health systems in Ecuador is funded by the State's general budget, extra-budgetary funds, emergency and contingency funds and funds from both national and international projects and agreements (PAHO, n.d.). There has been an overall increase in national health spending from the year 2010 which was $1.153 billion USD to an increase of $2.570 billion USD in 2015 which represented 9.2% of the GDP (PAHO, n.d.). Persons able to seek medical attention in public centers are those under the Social Security System and the institutions of the MoH (Ecuadorian Social Security Institute) which includes Rural Social Security, Armed Forces, the National Police and the health services of some municipalities (PAHO, n.d.). The national healthcare system accessible to the public provides free medical care to all residents regardless of income level. Therefore, consultations, treatment and all costs incurred by one's visit are covered by the public sectors hospital and clinics. This includes remote and rural areas where physicians, dentists, and nurses are required to perform a one-year "rural" post in order to complete their degree requirements for professional licensing (PAHO, n.d.). In larger cities, these hospitals can experience long lines, shortage of public health staff, or reduced medicine and hospital equipment in circumstances of high volume. The private sector of healthcare in comparison includes those of public health insurers and companies that offer prepaid medical insurance cover for the 3% of medium and high-income populations (PAHO, n.d.). This is due to some private facilities which require expensive treatment and services to its patients. For those who seek healthcare systems maternal and reproductive health, child health and the health of adolescents and disabled are among the categories for treatment and frequency of cases.

2.6 Non-communicable Diseases in Ecuador

The CDC defines non-communicable diseases (NDC) as chronic diseases that cannot be transmitted person to person and usually follow a long duration course of infection with slow progression (CDC, 2013). These diseases do not stem from an acute infection and are known to cause premature morbidity, dysfunction and reduced quality of life. According to data collection from a health survey in 2011 and 2012, there has been a moderate decline in the national prevalence of height retardation or chronic malnutrition with a reduction of 15% from 1986 levels (PAHO, n.d.). Although, the prevalence of chronic malnutrition, represented as low height for age in indigenous populations was 42.3% which is considerably high and nearly twice the national average of 25.3% (PAHO, n.d.). Among the highest causes of death for both men and women populations were hypertensive diseases which rose from 4.4% in 2000 to 6.6% in 2013 (PAHO, n.d.). In 2014 the top cause of death for men was cardiac ischemia while the highest for women was diabetes. The representation of mortality attributed to noncommunicable diseases in Ecuador remains the highest cause of death in adults ranging from 30-69 years old (PAHO, n.d.).

2.7 Vector-borne Communicable Diseases

The Center for Disease Control (CDC) defines communicable diseases as an illness caused by an infectious agent or its toxins that occur from the direct or indirect transmission of an infectious agent or from an infected individual host, vector, or an inanimate environment (CDC, 2010). Among the variety of communicable disease present in Ecuador, the primary rate of infection cases derives from mosquito-related and water-related diseases. Dengue is a vector-borne disease endemic to Ecuador and a growing challenge for the country. Vector-borne diseases are illnesses caused by parasites, viruses and bacteria transmitted by mosquitos, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, snails and lice (WHO, 2017). Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans, as shown in dengue, transmitted by Andes mosquito's, and reported to be the most rapidly spread mosquito-borne viral disease in the world (WHO, 2017a, 2017b; WHO and WMO, 2012). Symptoms of dengue can be a challenge for non-public health personal to identify due to its wide range of symptoms from flu-like fever to potentially fatal severe hemorrhagic dengue. There are four strains of dengue endemic to the country while dengue (DEN1) strain is most commonly experienced (WHO, 2017b; WHO and WMO, 2012; PAHO, n.d.). Cases of dengue are most commonly found in tropical environments where bodies of water remain stagnant and uncovered which provides sources of mosquito reproduction and larvae growth. Almost 90% of all dengue cases in Ecuador originate from coastal populations in 2014. Annually an estimated 19,188 cases from all strains of dengue are reported with the highest prevalence in infection from populations between 20 and 49 years old which represents 60% of all cases (PAHO, n.d.). Populations under the age of 15 represent 50% of all cases and are to be more severe due to the underdevelopment of children's bodies to fight and handle the infection. Dengue is not known for its high mortality as annually there are 18 fatal cases per year (PAHO, n.d.). Other mosquito-borne cases of chikungunya virus, Zika and malaria cases can be found in coastal and rainforest regions but the case of infection and morbidity are far lower than those of dengue (PAHO, n.d.).

2.7.1 Water-related Diseases

Water-borne and sanitation-related diseases are one of the major contributors to the burden of disease and mortalities in large populations of the world. (WHO, 2016f; Hunter, 2003; PAHO, n.d.). Intestinal parasites are the second most frequent reason for visits to public health centers which account for 17.5% of all consultations for populations between 5 to 9 years old. The third most frequent reasons for households seeking medical services recorded in hospital discharges were due to diarrheal diseases and gastroenteritis with presumed infectious organs (WHO, 2016f; PAHO, n.d.). These problems particularly are frequent to children under the age of 5. In 2014 the third leading cause of mortality in infants under 1 year old was due to pneumonia which is associated with problems of malnutrition, family poverty and overcrowding in houses (WHO, 2016f; PAHO, n.d.).

Poverty is also one of the main drivers for vector-borne disease outbreaks and water-related illnesses. This is due to populations having a vulnerable socioeconomic status that lack access to vector prevention and control measures and healthcare infrastructure that can treat these illnesses. In addition, in areas where poverty is high, there is often less stress on proper health and hygiene practices which can increase the spread water-borne diseases (Mavian et al., 2018; WHO, 2018c). These cycles of disease infection and contamination further limit people's ability to rise above poverty because healthcare costs and time spent ill or treating illnesses are taken away from the ability to earn daily incomes and complete household duties. Disability-adjusted life years (DALY) is a tool used to calculate how a person's life years have been adjusted and effected by the tasks of disease, treatment costs, relapsed illnesses, livelihood activities effected, ability to access water and food, mental stress caused by these limitations and how these variables impact someone's total life years (personal communications, K. Krepple, April 1, 2019; WHO, 2018c, n.d.).

2.7.2 Infectious Diseases: Parasites

The frequency of hospital visits for illness related to parasitic infection is shared by large parts of the developing world. Excluding malaria, from the parasitic disease family, the remaining majority of these diseases are known as neglected tropical diseases (NTDs) due to their lack of attention in the public health community overshadowed by 'hot topic' mosquito and diarrheal diseases (Cartelle et al., 2015; CDC, n.d.). As defined by the CDC, a parasite is an organism that lives on or in a host organism and gets its food from or at the expense of the host (CDC, n.d.). There are three main classes of parasites that cause diseases in humans: protozoa, helminths, and ectoparasites (CDC, n.d.). Parasites are classified as an infectious disease, diseases caused by pathogenic microorganisms such as bacteria, viruses, parasites or fungi which can enable the disease to spread directly or indirectly from person to person (WHO, 2019). Therefore, the presence of these organisms in the environment and the rate of contamination directly affect a person's chances of exposure to the disease. Most commonly these diseases can be found in the majority of tropical and sub-tropical environments, of which Ecuador is not excluded from bearing this disease. Protozoa are microscopic one-celled organisms that can be free-living or parasitic in nature (CDC, n.d.). Due to their flexibility in shape, they are able to multiply in humans, which further strengthen their rate of survival and allow them to cause serious infections in humans from their multiplication in the host. These organisms while living in a human's intestines can be transmitted via fecal-oral-route, usually by contaminated food or water or from person to person contact (CDC, n.d.). In addition, protozoa living in the blood or tissue to humans are transmitted to others by an arthropod vector, therefore a mosquito biting an infected person to move to another can transmit the disease (CDC, n.d.). There are different classes of protozoa that can be infectious to humans, those most commonly reported in cases in Ecuador are; amoebiasis, caused by the protozoan parasite *Entamoeba Histolytica*, and giardiasis, a protozoan parasite Giardia intestinalis (*G. Lamblia and G. Duodenails*) (WHO, 2012; CDC, n.d.).

The second class of parasites is the Soil-transmitted helminth (intestinal worms) most commonly classified under the family of Intestinal nematode infections (CDC, n.d.). Over 24% of the world's populations are infected with soil-transmitted helminth mostly originating in tropical and subtropical areas. These are known for their large multicellular shape that can be visible to the naked eye in their adult stages of life (CDC, n.d.). This disease can be transmitted through eggs present in the feces of infected people and in areas that lack adequate sanitation services they contaminate the soil (WHO, 2019, 2017a). School-age children and pre-school children most commonly carry the burden of this disease. The number of infections found in this age group is estimated to be over 267 million pre-school children and over 568 million school-age children that live in areas where parasites are intensively transmitted and require treatment or preventative measures (WHO, 2019, 2017a, 2017b). The most common modes of transmissions for these infections can be from eggs attach to vegetables and by lack of peeling, cooking or washing the food in safe water these vegetables are later ingested along with the parasitic worm. In addition, eggs can be ingested by drinking contaminated water along with contact with contaminated soil, which then is exposed to the person's mouth. Contact with contaminated soil is most commonly the infection source for children that play and then do not wash their hands or put their hands up to their mouth while playing (WHO, 2019, 2017a). Another source of infection is due to hookworms hatching in the soil and once larvae mature they can penetrate the skin, this is a large concern for populations that walk barefoot on contaminated soil (WHO, 2019, 2017a). Soil-transmitted helminths cannot be transmitted directly person to person due to the incubation time larvae need in the soil to mature is around 3 weeks. The DALY of persons affected by these infections can range from minor infection to severe cases. Primarily, a person’s nutritional status is impaired as a result of the worms feeding on host tissues and blood which causes a decrease of iron and protein in the body (WHO, 2019, 2017a). Secondly, hookworms can cause chronic intestinal blood loss which can result in cases of anemia, which is quite commonly a lifelong condition carried by children infected multiple times (WHO, 2019, 2017a). The morbidity of this disease depends on the number of worms inside the host, therefore people with few worms usually do not experience symptoms or suffer from the infection. Those with heavier infections will start showing symptoms of diarrhea and abdominal pain, malnutrition, general malaise and weakness, and impaired growth and physical development (WHO, 2019, 2017a, 2017b). There is a treatment for this illness and is widely used by all health officials in countries showing high rates of soil-transmitted helminths. A deworming treatment can be administered to populations that are believed to be high risk to infections and can be done without previous diagnosis and should be administered once a year to populations with infections over 20% while de-wormers should be given twice a year for communities 50% or more infected (WHO, 2019, 2016b, 2006). In addition, once infected health officials along with non-health professionals can administer prescription medicines such as Albendazole (400 mg) and Mebendazole (500 mg) (WHO, 2019, 2016b, 2006). Within the species of Soil-transmitted helminths there are different types of intestinal worms, some of which most commonly diagnosed in South America are; the roundworm *(Ascaris lumbricoides*), whipworm (*Trichuris trichiura*) and hookworms of the new and old-world family (*Necator Americanus* and *Ancylostoma Duodenale*) both from the genus ancylostoma (WHO, 2017a, 2016b, 2012, 2006).

The third class of parasites is ectoparasites, most commonly referred to as a parasite that lives outside the host. Examples of these blood-sucking anthropoids are usually known as mosquitos, fleas, ticks, lice and mites all of which attach or burrow into the host's skin and remain there for extended periods of time (CDC, n.d.). The key difference between ectoparasites and the other classes is their ability not only to cause disease by themselves but also their more common and dangerous ability to become a vector for the transmission of other infectious diseases (CDC, n.d.). Within the tropics of Ecuador, these ectoparasites are quite active and can carry dengue, chikungunya, Zika, malaria, and others. As known in Ecuador and other parts of Latin America mosquito-borne illnesses have infected and claimed numerous lives along with causing severe cases of morbidity. The DALY of a population with continuous cases and a high prevalence of these diseases can be estimated to have suffered greatly to the cost of its disease and hosts benefit.

2.7.3 Diarrheal Illness

Cases of diarrhea occur worldwide and attribute to 4% of all deaths and 5% of health loss to disability (WHO, 2016f). Diarrhea symptoms can be very dependent on the source of illness caused by a host of bacteria, viral and parasitic organisms mostly spread through contaminated water with human or animal feces due to shortages of water, or lack of preventative hygiene and cooking or cleaning with exposure to infectious agents (WHO, 2017b, 2016f). Diarrhea is the passage of loose or liquid stools at a rate more frequent than personal normal rates. Gastrointestinal infection is often the primary symptom of diarrhea and depending on the type of infection, cases of diarrhea can persist for days or several weeks, which can be severe cases and life threatening due to loss of fluids (WHO, 2016f). Diarrhea can also spread from person to person when aggravated by poor personal hygiene and direct contact or exposure is made to feces or food with particles or spores of feces due to lack of handwashing with soap, near latrine services or food contaminated during irrigation, seafood and other causes (WHO, 2016f). Excluding HIV/AIDS, diarrheal diseases have the highest reported DALY among parasitic and infectious diseases globally (IHME, 2010).

3.0 Objectives of the Study

The intended outcomes of this project were to establish a willingness to pay (WTP) price that represents how much rural Ecuadorian communities are willing and able to pay for access to safe water services. Secondly to quantify how one’s healthy life years are affected by the burden of disease, specifically water-related diseases and the amplitude of one’s social, ecological and physical livelihoods impacted. Lastly, this research spoke to the larger global correlation between WASH and climate change. As the range of climate change impacts expands in intensity and frequency this directly impacts water and sanitation infrastructure, the quality and quantity of water sources and heightens favorable conditions for pathogens of communicable disease growth and reproduction increasing their rate of human infection and suitable environments. This objective was reached through social scientific methods and economic health models engaging with households on their valuation of water based on their current use of service, the sufficiency of water and quality and quantity attainable to each family. Further insight on household's health was drawn through disability-adjusted life years (DALY) surveys, centered around family's most frequent symptoms and illnesses experienced in the current year, access to health services and the frequency of visits, the number of days a member of the family is unable to work or attend school as a result of this illness and the believed source of infection/disease. Further information regarding the most common diseases in rural communities visited and those of water-related infection will be asked in greater detail in surveys with health professionals.

Data gained from these responses would contribute to the understanding community-specific health concerns and disease presence in the area; how one is healthy life years have been impacted by cases of illness and their lack of access to safe water services. In addition, the price attached to safe water access provided by family's interviews will determine the ability to implement a sustainable water project to acknowledge and account for payments for basic services households pay. Access to safe water purification systems signifies the first step to achieve a household's healthier well-being and livelihood through wage-earning jobs, free from disability attributed to continuous infections and long-lasting health consequences along with one's improved mental state frim reduced stress surrounding access to water in sufficient quantity and quality.

Another key goal of this capstone project is to understand the variety of effects climate change has on community water resources and disease presence. The impact of climate changes is the umbrella that influences and surrounds issues of water quantity and quality and the health of rural and urban populations. Both WTP and DALY surveys explore these outcomes in greater detail to ensure future generations are able to better mitigate or adapt to the threats of climate changes while accessing safe water services, free of contaminants and disease.

3.1 Hypothesis

If rural communities in Ecuador gained access to safe water services their healthy life years would be improved compared to those accessing unsafe water by reducing the burden of a water-related disease.

3.2 Research Questions

- What price are households willing and able to pay for access to safe water services?
- How has climate change impacted Ecuador and in what ways?
- What impacts has this had to WASH infrastructure and water resources?
- Has climate change exacerbated the range and presence of communicable diseases, specifically parasitic infections and what populations carry the weight of this burden?
- How has one's healthy life years been lost due to the burden of parasitic disease?

4.0 Designs and Methodology

Willingness to Pay and Disability-Adjusted Life Years Methods Studied

The "use" of water relates to individual entitlement to use water as a public or private good. This project determines how much a community is willing to pay (WTP) to improve their water supply and access (Motlaleng and Thukuza, 2011; Tussupova et al., 2015; Whittington et al., 1987). In economic terms, WTP is a measure to determine the maximum amount that an individual or community is willing to pay for a service. The World Bank, United States Agency for International Development (USAID) and Inter-American Development Bank (IBD) have described WTP as, “an absolutely essential method for any noticeable improvement in the rural water supply situation in the developing world” (Whittington et al., 1987).

The rising concern of water scarcity is one of the primary motivations to conduct WTP because people can determine how much they would pay for water based on different contexts. Through this understanding, strategies to reduce water insecurity in communities have taken shape to assess the current state of water quality and quantity in communities, provide useful recommendations, and introduce water supply infrastructure that can be valued largely for its benefits that will outweigh the costs of the project (personal communication, R. Lokina, March 15, 2019). The demand for clean and accessible water is a critical issue and would be one of the human civilizations biggest failures do not provide adequate and safe drinking water to all life. Water is a commodity that has economic value because people are willing to pay for it rather than go without. The UN General Assembly has declared drinking water a basic human right, compelling governments to actively invest in and facilitate access to freshwater (Yu & Packard, 2012). After basic needs for water consumption are met, people buy water based on the price compared to other items at similar prices, which assign a value to water. Therefore, the value of water for survival is infinite and people would be willing to pay any price in order to gain access to safe and clean water. Willingness to pay assigns a value of life-based on someone’s willingness to pay for a small reduction in the probability of negative externalities from the lack of safe water. If a person pays less for this value it does not necessarily mean they do not value their life but based on this situation and therefore represents their ability to pay for the resource which could be the maximum amount an individual is able to afford (personal communication, R Lokina, March 14, 2019).

Willingness to pay determines what consumers are willing to pay in order to receive water from improved sources (Sengupta and Polle, 1997). The variables that can influence someone's willingness to pay can stem from the perceived benefits, income, water changes, water value in relation to other household values, women's time, existing sources, and credibility (Sengupta and Polle, 1997). This should only be conducted after the basic needs for water security are met in accordance with Millennium and Sustainable Development Goals and world health standards. The ability for someone to pay for improved water sources is valued against convenience, amenity and economic benefits that a new source of water supply can give compared to the preexisting structure. The strength of a WTP is its ability to incorporate the avoided expenditure households spend on issues that relate to water supply and adequacy. This can be discovered in the WTP surveys and interviews which discussed added costs to water-related to medical costs from illness that required medical attention and treatment due to water quality, emotional and bodily distress from walking distances to collect water, environmental pollution that can lead to other health illnesses and exposure to harsh contaminants and environmental conditions. This implies that residents incur additional costs of water bills and also the costs of personal water treatment externalities (Motlaleng and Thukuza, 2011). The WTP reflects peoples true economic value placed on water and their preferences for the resource in question that needs to be improved (Motlaleng and Thukuza, 2011).

The success of improved hygiene and sanitation stems from the ability to incorporate water and sanitation conjointly. By developing the infrastructure required to support current and future populations attaining both safe services free of contamination and accessible on the premise contribute significantly to the success of achieving a low DALY score, representing the burden of disease that causes early mortality and/or disability is lower and therefore fewer people are impacted by the presence of the disease (WHO, 2018c, n.d.). In order to actively understand the burden of disease present in communities and the result of water and sanitation improvements, demographics and environmental change, income, policies and investments, education, technology, management of infrastructure, community and public sector involvements need to be monitored and weigh into projects sustainability and implementation (Prüss-Üstün et al., 2004). When there is an absence of collective WASH planning to improve both sectors but rather only improving one, such as water, then the results would not be as high due to rates of disease associated with the lack of development in sanitation systems and/or hygiene services because the other disease transmission avenues have not been simultaneously improved. This is particularly true in communities that have a high fecal-oral pathogen presence. To introduce a single intervention in isolation in hopes to break an infection pathway may produce results that are negligible to the overall disease reduction (Prüss-Üstün et al., 2004). For these reasons, it is vital to consider WASH as an interconnected part of a system of pathways of disease transmission. In addition, it is important to understand developed infrastructure for sanitation and water must involve the treatment of water for consumption and use. Often times water systems are constructed solely for water containment but fail to properly treat and routinely test the safety of the water for bacteria or parasitic presence. If water harbors microscopic contaminants it will continue to infect human hosts, this is why management of water supply and sanitation services often involve water resource management which includes control and treatment of insect vectors of disease and soil-borne helminths (Prüss-Üstün et al., 2004). The research will continue to highlight the results of improved access to water sources and its impact to individual’s exposure from water-related sources.

To address the price individuals are willing to pay (WTP) for access to safe and improved water sources, this project collected data in a replicable manner as practiced by USAID and other organizations (Whittington et al., 1987). WTP methods capture both the economic value people attach to improved water sources and the social value to improve water quality and quantity, which can vary across individuals based on location, age, and gender, among other factors (Motlaleng and Thukuza, 2011). Willingness to pay research referenced the contingent valuation method (CMV) to estimate the value a person attaches on a good by asking directly to report their WTP rather than to infer them from observed behaviors in regular market places (Motlaleng and Thukuza, 2011; Tussupova et al., 2015; FAO, 2000; Whittington et al., 1987). The success of a CVM has been demonstrated by numerous government organizations that work in rural developing countries (Tussupova et al., 2015; Whittington et al., 1987). Willingness to pay survey questions follow a similar baseline model presented by The United Nations Centre for Human Settlements in the community based environmental management information systems titled Guidelines for Assessing Affecting Demand of Communities for Environmental Infrastructure (United Nations Centre for Human Settlements [Habitat], 1995).

To understand the basic minimum price households could pay for access to safe water services, qualitative research was collected through surveys and key informant interviews on questions that pertain to how a person's life years have been impacted by the lack of access to safe water. This includes how someone or their family has been affected by drinking contaminated water and lack of access to sanitation services. The impact water-related illness has on a person's healthy life-years can be found through interviews using a DALY method. This term is used continuously in the WHO Burden of Disease Reports and Institute for Health Metrics and Evaluation (IHME) Reports to understand more specifically how one's DALY can represent a one-year loss of a person's "healthy life" (WHO, 2018b, 2018c; IHME, 2010). DALY's are important to understand the gap between a person's current health status and an ideal health situation where the entire populations live to an advanced age, free of disability and diseases (WHO, 2018b, 2018c). Further details on the Global Burden of Disease (GBD) DALY calculations formula and methods used are provided in Appendix C Section 1.

Qualitative in-depth interviews focused on WTP and DALY's surveys used techniques to understand how someone's life has been impacted by drinking contaminated water, lack of sanitation services, quality and quantity of water they have access to and how much households would pay in addition to other basic service payments to gain access to clean water services. In addition, to understand the full impact contaminated water has on someone's health and life, qualitative and quantitative interviews were conducted with healthcare professions working in these rural communities. Health and hygiene quantitative interviews helped understand what are the most common cases seen, percentage of water-related illness treated and the extent of access people have to healthcare services in the area. Information gathered from healthcare key informants helped conduct a representative DALY calculation to understand the burden of parasitic diseases in one's life. The data collected on these issues referenced countrywide reports collected by WHO/UNICEF Joint Monitoring Program, World Bank Reports and Ecuador's 2010 Census Data and when variables were not accessed due to time constraints data from these sources were supplemented into the DALY calculations.

For application in these communities in Ecuador and elsewhere: a mixed-method approach was best represented for the data and research collected as this gave myself the opportunity to be fluid, revisit sites, and develop my research in the field when uncontrolled variables arose. Methodology for the collection of data for WTP, DALY and healthcare surveys explained above were conducted through semi-structured interviews with both open ended and closed questions. Interviews both formal, informal and focus groups have proven to be a useful method for collecting a wide range of data from factual demographic data to highly personal and intimate information relating to a person's opinions, attitudes, values, beliefs, past experiences, and future intentions. There are many advantages to conducting interviews because there are high participation and opportunity for feedback and conversations that may not be directly answered by the question but provide a deep understanding from that person's experience on the subject and allow for further questions to be asked. Also, interviews can investigate if respondents' answers are unclear or incomplete but repeating the answerback or asking for further clarification at the moment.

4.1 Methodology of Data Collection

Ecuador's official language is Spanish and to ensure interviews were communicated correctly and comfortably all research was conducted in Spanish. Data collection used both a translator and no translator but accompanied by a partnered organizational team member. In the Amazonian Basin, region populations speak both Quechua and Spanish as official languages; therefore, a translator was used in the field for assistance in interviews. This translator was from Ecuador and had worked in other communities in this region for over 10 years. In this community, interviews were recorded to be transcribed every day after leaving the field. This was the only community where the recording was used as a tool for data collection and verbal consent to use this recording device were asked to each participant while presented with the consent form. It was important to verbally explain the consent form along with an introduction of myself and my research so people understood my presence and also to avoid uncomfortable situations for participants who were not literate. While partnered with the organization Grupo

Social FEPP in Ecuador, field members who have worked in the communities for extensive amounts of time explained my arrival and in days coming what research I would conduct in the area. Once in the field initial meetings with the president of each community and his staff or municipality offices were greeted, explanation about my research was communicated, and in some cases, the president, staff members, or municipality members accompanied me for part of all interviews. The implication of an authoritative presence that accompanied my research in some circumstances will be explained in detail in the ethical concerns section.

To further explain a mixed methodological approach that was used in the field this allowed myself to use formal and informal semi-structured interviews and key informant focus groups to collect data. Formal interviews that were arranged with a predetermined date and time either suggested by my partnered organizations or from community presidents. Most commonly used were informal interviews which did not have a predetermined time, rather myself along with my field partners went to different people's households and explained my research and asked if we were permitted to sit down and ask them questions. Focus groups were used only when meeting with community leaders, water committees and a few cases of interviewing a group of mothers working together. Interviews would take around 15 minutes to complete and always allowed room for further questions, stories and occasionally lunch or tea. Informal interviews allowed this flexibility to stay longer with households if they chose. In addition, in situations when community staffs were running late or plans changed now the fluidity of my schedule worked greatly to my advantage to remain available for new circumstances and plans. My interviews followed a random sample methodology and with the support of partnered field members maps, boundary lines, and community-specific information supported my analysis of each area studied.

4.2 Experiences in the Field

Anticipating some fluctuations once in country I was prepared for total sample size from 4 communities with 40 interviews, accounting for 10 interviews in each community. These anticipated sample sizes for each community were very different from what I would actually completed due to some communities wanting everyone to be interviewed, as seen in the Alta Florencia community or the increased number of communities I would work in as shown in Loja Province. The majority of my fieldwork was completed in rural communities within Loja Province, four hours from Loja City. Originally Grupo Social FEPP and I together had decided I would conduct my research in three different communities. In total, I ended up working in twelve communities within the Loja Province and one in the Orellana Province. This allowed me to collect large amounts of data from 75 interviews in the field, which included 50 households studied in Loja, 20 households in Orellana, three doctors, and two affiliated organizational members.

Working with such a large sample size led to some challenges to remain consistent with interviews and not being able to synthesize data until after each community has been interviewed. My sample sizes within each community have ranged depending on the size of the community but an average of 10-15 households was interviewed per *parroquia* (area). In addition, one challenge while working in Loja was the absence of a translator. It was decided that I would conduct interviews myself in Spanish with the support of Grupo Social FEPP field team members to help me. While my Spanish is intermediate, I am not fluent therefore communities speed, accents, and different 'street' language expressions posed some challenges to understand. Since my vocabulary pertinent to my research is advanced I was able to understand the majority of participants' responses, but when requiring clarification, a Grupo Social FEPP field member was always present to draw maps or use different vocabulary to ensure I understand the context. While the data collected was a larger sample size than predicted and there were some challenges presented, the data gathered from these interviews with households and key informants was more than sufficient to draw conclusions about the qualitative and quantitative issues existent in these communities.

4.3 Confidentiality and Ethical Concerns

Preceding the onset of field research there were many steps involved to develop a clear set of deliverables and coordination to ensure confidentiality that data could be delivered in a concise and straightforward manner. A complete proposal for my intended research, interview questions, development of methodology and anticipated ethical concerns, consent forms, and background country and topic literature were developed and completed within the Human Subjects Review Application submitted under as a research proposal to the SIT Institutional Review Board. Once my application was approved prior to arrival in Ecuador interview questions for both DALY and WTP surveys were written and translated into Spanish to be sent for approval by organizations working with me, community leaders and affiliated field personal. A list of these interview questions and consent form are provided in Appendix B.

All interview questions that were used in the field were those approved by the Institutional Review Board (IRB). In addition, consent forms were written in Spanish to be read and shown to all participants prior to beginning the interview. Any questions the interviewee had could be asked and only if they agreed verbally to participate in my research and provided their signature could the interview proceed. In one community where instruments for recording were used a verbal explanation of the tool was given and consent by the individual was recorded in each labeled recording. Consent forms along with all data collected in the field were kept in a private location not accessible to the public to ensure confidentiality. Data collected in the field was transcribed and recorded each night on a computer with lock safe protection.

I mitigated ethical concerns that were encountered during the course of fieldwork conducted in Ecuador to the best of its ability along with recommendations from SIT staff and WaterStep supervisors. One *parroquia* (area) within my study had generated some ethical concerns due to their choice of participants to be included in my sample which undermined my ability to ensure participants were random. Also, their encouragement and suggested numerical data motioned to participants and their presence alone as a higher authority figure was factored into participants' responses. Overcoming these challenges was met with both proper ethical procedures to explain to accompanied staff the importance of participants not having influenced responses and the meaning of a random sample approach. Proper in the field cultural perspectives and unwritten guidelines to navigate different cultures were understood and to ensure relationships remained positive, consequently the bias influence continued in three of the six communities in this *parroquia* (area). As a result, all willingness to pay questions regarding the quantity of water used per household, additional water needed, and the minimum willingness to pay price for access to safe water were omitted. These questions were those with the highest biases and the concerns this has on the future success of this project were also key reasons for my omission of WTP data in my analysis. The remaining three communities studied in the *parroquia* (area) the following day did not have staff members present but to remain consistent with my omission of certain questions in the WTP, these communities were only asked the same as communities in the prior day.

5.0 Findings

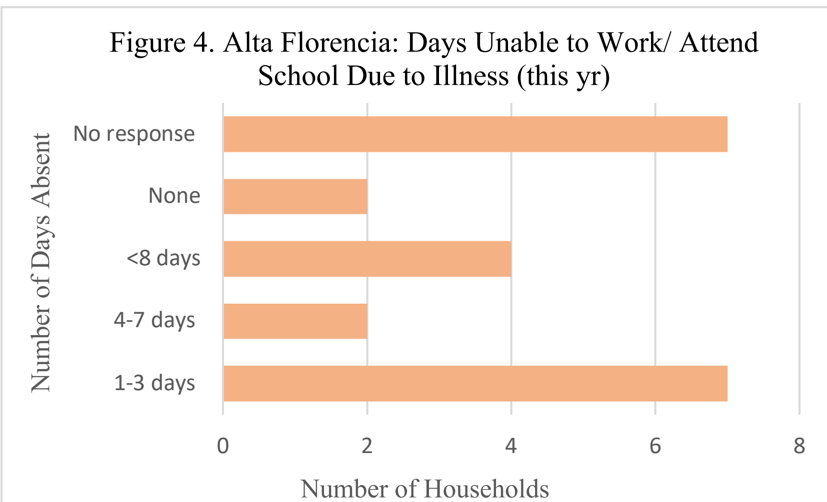
Community Health Assessment (DALY) and Willingness to Pay for Safe Water Project

5.1 Orient/Amazon Region: Orellana Province, Alta Florencia *Parroquia*

Positioned within the Amazon Basin region, Alta Florencia is one community in the Orellana Province, a province within the Orient region of Ecuador, covers approximately 21,675 square kilometers (km2) and in 2010 had a population of around 126,396 residents (City Population Database…, 2019). This province includes communities within Yasuní National Park and additional *parroquias* (areas). Alta Florencia is a small community alongside the Napo River about 20 minutes by boat from Peru's Amazon. This community consists of 22 households while only 20 families permanently reside there. All families that permanently reside here were included in the study which includes 20 households.

Prior to conducting my research to better understand the region of my study, I gathered information in regard to an oil spill that occurred in this province which contributed to water contamination within the Napo River and as a result, the community's expressed concerns about this pollution as later exhibited in my research. Community members were appreciative to receive these tanks but after this compensation, there was no training to instruct people on how to harness rainwater collection or information about the river contamination. In addition, there was no follow-up response and little to no further compensation or intervention to help these communities. The donation of rainwater tanks to this community is one of the only reasons households now have access to rainwater but many still depend on the river for all other water-related activities and new community members lacking rainwater tanks have no choice but to use the river. Further details on the community's health and use of rainwater and river water will be explained below.

The majority of these interviews were with mothers of the family, although they are not the leader of the household as that is the man's role, underlyingly they know the most pertaining to family health issues and take on the responsibility to care for the children and other household duties. The average age of respondents was evenly spread ranging from 30 to 61 plus years old. DALY surveys were asked first to understand underlying health issues the family experiences and where they believe these issues are from or connected to. Households expressed members of their family getting symptoms of diarrhea, headache, fever, stomach pain, diarrhea, dehydration, skin irritation and more very frequently. As one interviewee explained, “We usually have two months well and the third month sick, every year, it’s a sickness cycle” (Interviewee 55, June 9, 2019). The most repetitive response was from symptoms of diarrhea, stomach ache, fever, flu, skin irritation, ear fungus, and vomiting. Over 70% of respondents tracked these illnesses back to the believed source of contaminated water and 20% believed it was from parasites which inevitably were in the water or food. As Figure 4 references above, the number of times within the current year a family member visited the hospital because of an illness, the response ranged from 2-4 times this year (25%), every month (20%) or 5-6 times this year (15%), the majority of responses also included visiting the hospital only when they are sick. Next, respondents were asked the number of days someone in their household was unable to work or attend school due to this illness. This question is important to understand how their healthy life years have been impacted by illness and disease. While children under pre-school age count not be accounted for due to their age, it can be predicted that these numbers would be higher to account for days young



children were sick as they are the majority of those with diseases. As one member of the community talked about his daughter recently ill, "she had many parasites in her and even after medicine she wasn't eating well and had to take vitamins to help… she is only 7" (Interviewee 68, June 10, 2019).

Following the DALY survey WTP questions were asked to understand households' access to water and sanitation services, to determine if they prioritized different water sources for different uses, the amount of water used per day and if this is enough along with their interest in a water project to gain access to safe water services and how much could they pay at a minimum per month for this service. From the 20 families interviewed 0% had piped water access into their household or on the premise and 80% did not have access to sanitation services. All families expressed their first choice of water for drinking and cooking was rainwater but this was not always available to them. Therefore, all second options of water for drinking and cooking were to use the river water or streams. "When there is no rain we go to the river…" (Interviewee 56, June 9, 2019). During the dry season winter months (June to September) there is a decreased amount of rainfall and over 90% of families usually use the river water. All households stated using the river water was the main source for washing dishes and clothes, using the bathroom, and bathing. On average a small portion, 35% of households boiled the river water before using it to drink. One continuous response was not to boil the water but "let the water sit and the sediment will settle at the bottom than we drink from the top" (Interviewee 71, June 10, 2019). Over ¾ of the households interviewed showed me their rainwater tanks and their own 'filter systems' they had constructed. These filters were mosquito nets most likely given to the community and wrapped around the top pipe to filter the water from large contaminants and mosquitos from going into their tanks. As one woman told me "I do not have to boil my water because I have my filter and this makes it cleaner" (Interviewee 63, June 10, 2019). Images from some of these households with these filter systems are provided in the Appendix F Section 4. The amount of water households use for daily drinking and cooking purposes on average was 10-15 gallons (1.68 cubic meters (c3)) per day, while 25% only used 5 gallons (0.54 c3) for their household. To follow this question families were asked if they had a sufficient amount of water for their family for drinking and cooking purposes. Over 85% of families stated they did not have enough and when they needed more they used river water and a stream if accessible. In order for families to feel comfortable with the quantity of water needed daily on average families felt that an additional 10 gallons or another 500-gallon rainwater tank would meet their needs. Due to the lack of sufficient and healthy quantities of water available for families when asked how they managed life without enough water people responded: "when the water is low we don't drink and reduce consumption to save it" (Interviewee 58, June 9, 2019). The health repercussions of these situations' respondents answered to will be analyzed in greater detail in the discussion sections to completely understand one's healthy life years impacted by consuming less than sufficient amounts of water.

Lastly, households were asked if coverage of water supply expanded to include this area would they want this project and how much would they be willing to pay at baseline per month for access to safe water. All respondents agreed they would like the project and expressed a great need for safe water. The largest portion of households expressed a WTP payment of $2.00-2.50, while the second-largest percentage did not specify a price but referenced their ability to pay similar costs as electricity payments (ranging from $4.00-7.00) or a price that was dependent on how much water they would use. "We want the water, we need it, we also need latrines to stop going in the river and getting sick, the river is contaminated not only with oil and feces but also with dead animals", these expressions were empathized by countless households in the community (Interviewee 71, June 10, 2019).

5.2 Andes/Sierra Region: Loja Province, El Arenal *Parroquia*

Due to the complexity of boundaries within towns and communities within the same area, the exact descriptions of locations included in my study area are described in Spanish than described in English with similar vocabulary. In addition, hand-drawn maps of each *parroquia* and its communities can be found in Appendix F Section 3 to indicate water sources, households' locations and where future installment of safe water purification systems would be constructed.

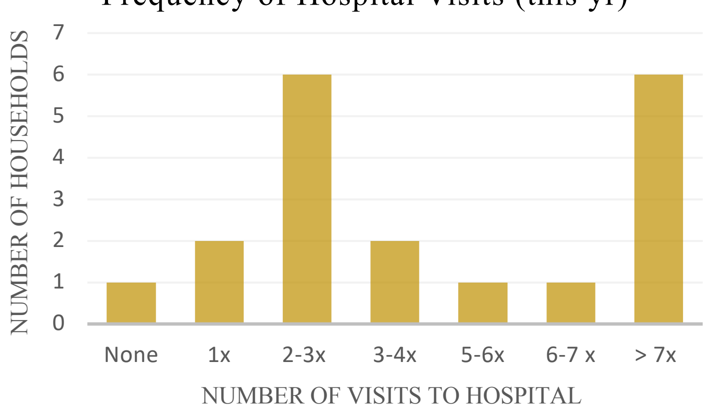
El Arenal es parroquia de Canton Puyango, Amarillo es barrio de la parroquia de Arenal todos en la provencia Loja. Located within the Province of Loja, a region of Ecuador, El Arenal is a *paroqquia* (area) of Loja and labeled a *parish* (town) of 28.4 km2. El Arenal is located within the Puyango *Canton* (sector) and in 2010 had a population of 997 people (City Population Database…, 2014). Within the boundary area of El Arenal, there are two *barrios* (communities/neighborhoods) of Amarillo and Valle Nevo. Both communities comprise of small populations and rural landscapes (*campos/pueblos*) within El Arenal's municipality. El Arenal and Amarillo were included in my study area because Grupo Social FEPP WaterStep Org., the Municipal Government of Alamor and El Arenal *parroquia* and Manos Unidas de España Fundación will begin the construction and installation of a clean water project in these two communities. WaterStep water purification systems M100 and bleach makers will be established in this region for use to build onto preexisting infrastructure to provide access to safe water in these communities. Additional projects outside of WaterStep's safe water project will be funded by designated partners on the installation of two agricultural systems for irrigation and 100-agribusiness production integral space (*systems integrals de production agro peqaria*). The total costs of all projects are estimated at $137,918 USD. The construction and implementation of the WaterStep's water purification system and costs associated with development and installation is estimated at around $1,350 USD (Interviewee 35, July 5, 2019). One M100 water purification system will be installed on present water infrastructure that diverts water from the streams of Vertiente La Luma and Vertiente Ciano Nuevo in the community of Amarillo. In addition, an M100 system will be installed on former water infrastructure from the stream of Vertiente El Colorado in El Arenal. WaterStep's bleach maker system will be used in a community outside of my study area but within El Arenal's *Parroquia* in the barrio Valle Nevo where households do not use a communal piped water system. This area instead relies on individual access to ponds and local streams with individual hoses/pipes to water tanks on the premise outside households. Therefore, for safe water to become accessible to this community a water committee will be responsible to generate and disperse bleach produced by WaterStep's system each month providing 1 gallon of bleach to each family for a set price to clean and purify their water (Interviewee 35, July 5, 2019).

For the communities included in my study, the projected safe water systems project has already been financed and supported to include large water receptacles, the construction of receptacle-based platforms, enclosures for the system, a water committee, and maintenance for the system to be used. The M100 system suitable for a variety of locations will be fit to the water tanks receiving water from catchments in the streams diverting water to the new component of the system. Water will then be filtered through the M100 system and into the tank which will be connected to water pipes currently in use for the community household water access. The baseline minimum price for this system to be maintained and sustained is $3.00 per family per month. Through my work with Grupo Social FEPP field team members, I was able to understand these systems present infrastructure and the processes for implementing a safe water project of this size. Community population assessments, infrastructure development, and planning have all been completed by Grupo Social FEPP who had worked in this region to construct one of WaterStep's largest water purification systems which provides clean water to five communities in 2018.

Included in my study area of El Arenal and Amarillo, a total of 19 households were interviewed along with one interview with a doctor working in a clinic within El Arenal's community. In total 90 families live in El Arenal and 30 families live in Amarillo. The *parroquia* of El Arenal includes Amarillo therefore; both communities in this analysis have been represented as one. The importance of conducting a WTP in communities that are expected to receive a safe water system can be useful to understand the communities value placed on safe water along with the minimum price they feel able to afford based on their circumstances. In addition, when communities feel their health concerns have been known, there can be a relief to know efforts are in place to prioritize their ability to gain access to safe water services. This data can be used to compared households baseline price to the sustainable target payment of $3.00 per family per month and further conclude the project's sustainability. With communities unaware of this target payment value I was able to understand real-life price values given to safe water services compared to other basic services families pay for. The data from both communities were first analyzed independent of each other but shared similar results in regard to the DALY questions. Responses varied in their WTP questions as many households in Amarillo pay less for water services currently, therefore, their WTP for clean water was based on current payments. In addition, there are income differences between the two communities as El Arenal is the *parroquias* center and has access to different jobs, accessibility to services, and holds the municipality center. Amarillo in comparison is more secluded and consists of only households without a town center.

Included in the analysis of this study area the majority of respondents were mothers of households with the age of participants from upper 30's to over 61 years old. On average the size families currently living in households were either two people of which they were older and had children who moved out or families of around seven people. Over 74% of participants said themselves and their younger children experience symptoms of parasites, stomach ache, and diarrhea frequently. Families that had younger children always stated children suffered the most from parasitic infections and needed continuous treatment. Parasites from contaminated water and the source of water used by families were almost exclusively believed to be the source of illness. Some attributed the increase in flu symptoms to the environment and climate change. The majority of respondents expressed great concern in the water they drank being contaminated with some explanations stemming from animals' feces in the water which they then consumed, children, not washing their hands after using the bathroom and eating food or sharing food with others and "bichos" (parasites) coming from the river and main water sources. Subsequently, respondents were asked the number of visits to a hospital or clinic someone in their household made due to these illnesses this year, see Figure 5 below. While not all these visits were solely for parasite infections many respondents expressed on average visiting the hospital 3-4 times a year every year specifically for parasitic infections and receive treatment with medication. Due to

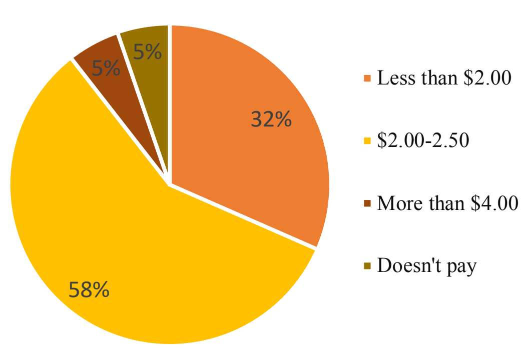
Figure 5. El Arenal: Households Frequency of Hospital Visits (this yr)



these illnesses, 62% of responses regarding the time a family member was unable to attend work or school this year was between 1-3 days. “My kids are younger than school but are sick every month especially in the summer…it’s from the water” (Interviewee 15, June 25, 2019). Consequently, this score does not reflect those children under the age of pre-school that have illnesses.

Willingness to pay questions addressed the following water-related quantity and access information to understand the value to the attached final questions regarding a households WTP for safe water. Almost all households (62%) had piped water into their house or on its premise as acceptable by WHO piped water access standards (WHO, 2016). The source of water from households came from two different streams within the community. Piped water is used for all activities from drinking, cooking, bathing, washing clothes and bathroom use. 94% of respondents either have access to sanitation services in some basic form inside or outside their home and 100% stated having both water and soap for handwashing near the latrine. Since this *parroquia* has water meters connected they were able to give exact quantities of water used per month for all activities represented in cubic meters (c3) and how much they currently paid for this service.

Figure 6. El Arenal: Current Payment for Water Services



The difference in payments was between communities rather than households within the same community. This is because as shown in Figure 6, those residing in Amarillo pay on average less than $2.00 for their water compared to El Arenal households where the majority pay $2.00-2.50. The differences in current water payments reflected in the household's response to the amount they were willing to pay for safe water, see Figure 7. Combined El Arenal and Amarillo WTP repossess reflected in Figure 7, demonstrate

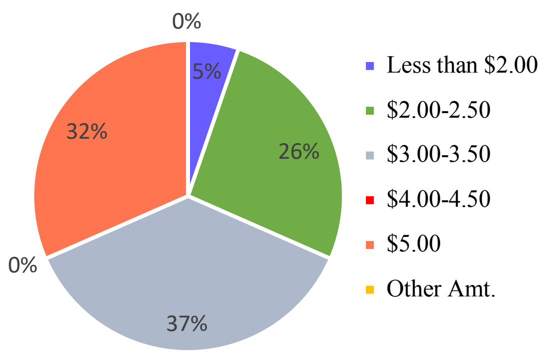


Figure 7. El Arenal: WTP for Access to Safe Water Service

37% were willing to pay $3.00-3.50, 32% were willing to pay $5.00, and 26% were willing to pay $2.00-2.50. Separating the two communities resulted differed between El Arenal households willing to pay between $3.00-5.00 while households in Amarillo expressed payments of $2.00-2.50 were appropriate. All participants in my research responded yes to having an interest and wanting a clean water project in their area to further express their need to not use contaminated water for their health.

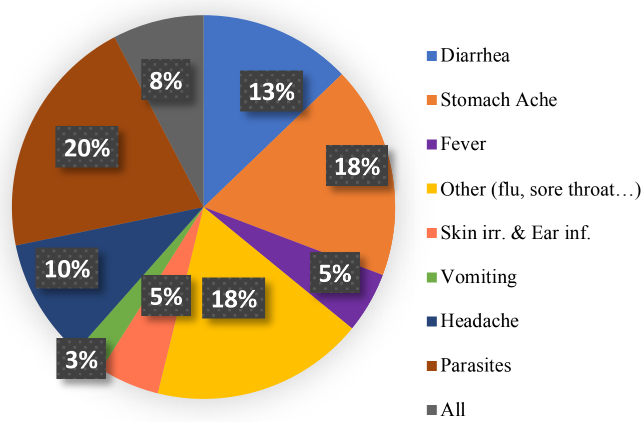
5.2.1 Chaquinal *Parroquia*

Chaquinal parroquia de Canton Pindal, siete barrios de Chaquinal, todos en la provencia Loja. Located within the Province of Loja, a region of Ecuador, Chaquinal is a *parroquia* (area) of Loja, lying within the Pindal *Canton* (sector) and is labeled a *parish* (town) of 17.4 km2. As of 2010, the population of this parish was 1,089 people (City Population Database…, 2014). Within Chaqunial's *parroquia* (area) there are seven *barrios* (communities/neighborhoods). Six out of seven of these communities were included in my study area as one community was excluded due to households of Palmitas not using the communal water pipes that connect to the main Rio de Chaquinal, the source of piped water connections to all other communities. A safe water project for this area does not have a predetermined start date due to funding and project costs being determined by all parties involved. In May of 2019, the Pindal Municipality changed leadership and is in a position to govern funding for projects in Chaquinal's *parroquia*. Therefore, Interviewee 35 believes the project could resurface for further deliberation in the year 2020 (July 5, 2019). The funding required for this project cannot be compared to El Arenal's *parroquia* due to all households in each of the six communities are without meters along with a percentage of houses requiring piped connection to the water system which will inquire further expenses. If this project were to be completed it will entail WaterStep's M100 water purification system to be used on the preexisting water diversion and collection infrastructure accessing water from Rio de Chaquinal to six of the seven communities' households' individual access (Interviewee 35, July 5, 2019).

The six communities that were included in my study area of Chaquinal *parroquia* were; Chaquinal the largest town and municipality of the area along with the communities/ neighborhoods (*barrios*) of Carrizal, Gramales, Faicial, Callancas, and Tulipan. Similar to data collected in El Arenal's *parroquia*, all communities within Chaquinal's *parroquia* will be analyzed as one. In each community, 3-4 households were interviewed for a total of 18 interviews along with one interview with a doctor working at the public hospital located in Chaquinal. As stated in my ethics section the results from this *parroquia* contain biases due to those, which accompanied me to interviews by mentioning specific water quantities and WTP values to participants being interviewed. Therefore, due to these influences, the willingness to pay question in regard to how much households could afford to pay for monthly access to safe water was omitted along with the quantity of water questions. The reasoning for this was decided by myself since suggested responses could have the ability to change perceptions of payments and the success of the project for the future.

The majority of participants were mothers of families with 33% being older than 61 years old. The average size of families ranged between 44% having 2-3 people, 27% having families of 6-7 people and 16% having 4-5 people currently living in the household. Families were asked the frequency of symptoms, see Figure 8, and they believe the source of these illnesses were from the contaminated water they used, the lack of handwashing especially in children and the environment. An additional believed source of illness that was shared here and not in other communities was one's contact with chemicals, pesticides and other pollutants used in their field of work which usually was in the agriculture sector. Fewer participants were open to discuss the frequency of parasitic infection and treatments, which were mentioned as 20% of the symptom's families had experienced, although one household described symptoms that related to parasitic infection of frequent diarrhea, excessive drool when asleep and bloated or bulging stomachs. The average time's families visit the hospital due to any one of these illnesses this year was most frequently (39%) every month or every other month, following (28%) 2-3 times this year. As a result of these illnesses, participants were asked the number of days this year unable to work or attend school for any member of the family. While 90% said they usually miss 1-3 days this year 33% expressed they do not miss any days. As stated in prior research the number of days missed does not account for children younger than pre-school and therefore cannot be a complete representation of days impacted by illnesses in each family.

Figure 8. Chaquinal: Frequency of Symptoms Experienced per Household



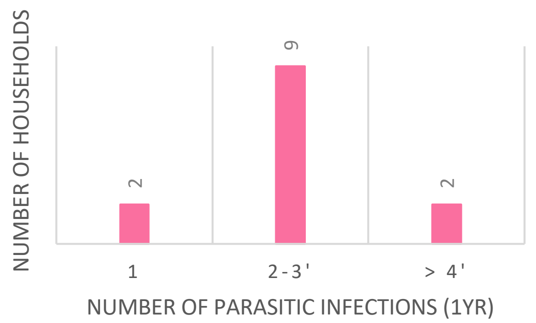
Willingness to pay surveys were less informative due to biases which eliminated most questions asked, nevertheless, all but one household interviewed had access to a latrine inside or outside their house with 94% having a latrine outside the home. All respondents access to a latrine confirmed to also have water and soap close to the facility for handwashing. All participants rely on piped water on the premise for all purposes but unlike other *parroquias* in the region, families here do not have 24/7 access to water in the system. Most families expressed every morning they do not have water for around 1-3 hours and believe this is a result of the system being used for to many houses or the streams being too low on water, especially in dry winter months (June-September). In regard to water service access, 83% of families claimed to not have a sufficient amount of water needed for their families. Due to the percentage of respondents who expressed a lack of access to water during the day, a follow-up question asked how they survive without access to enough water supply, "we don't drink in the morning when there is no water or if we can fill a bucket the night before we sometimes do that" (Interviewee 43, June 28, 2019). All participants in my research responded yes to having interest in and wanting a clean water project in their area.

5.2.2 Alamor *Parroquia*: Health Assessment: Pre and Post-Safe Water Project

Alamor es la Parroquia de Canton Puyango. Cinco barrios en la Parroquia es Guápalas, Trigopamba, BuenaVisto, Gramas, Naypiraca*, todos en la Provincia Loja.* Located within the Province of Loja, a region of Ecuador, Alamor is a *parroquia* (area) of Loja, the *Canton* (sector) of Puyango and is labeled a *parish* (town) of 239 km2. As of 2010, the population of this parish was 8,296 people (City Population Database…, 2014). Within Alamor's *parroquia* there are five *barrios* (communities/neighborhoods) that lie within the area and were included in my study; Guápalas, Trigopamba, BuenaVisto, Gramas, and Naypiraca. This area holds the first safe water purification system for the *parroquia* and the largest safe water project WaterStep has participated in. WaterStep, Grupo Social FEPP, the Municipal and Government of Alamor's *parroquia*, and Manos Unidas de España Fundación all participated in the completion of this safe water project (Interviewee 35, July 5, 2019). Completed at the beginning of 2018 this project provides safe water to all households in the five communities with direct piped water access to household's premise and inside their homes. The total costs for this safe water project were $70,000 USD which included installation of one M100 WaterStep purification system, two large water receptacles to purify water from preexistent water diversion structures, household water meters, water pipes, and water committee maintenance and daily use of the system (Interviewee 35, July 5, 2019). In addition, as this project has been successfully running for over 1 year the sustainability of this projects relies on the monthly payment of $3.00 per household for 15 c3 of water which is tracked on individual households' meters. Households which require more than 15 c3 can pay $1.00 for every additional cubic meter (Interviewee 1-5, June 19, 2019). These payments are collected by the water committee which is located in the community of Guápalas, also the location of the safe water purification system. These payments go towards maintenance of the systems as each tank contains 2,000 c3 and needs to be drained for cleaning every month. These tanks distribute water via pipes to households every morning, the water committee is responsible for running the M100 system which takes around 4 hours to purify the first tank and 6 hours to purify the second tank (Interviewee 1-5, June 19, 2019). In addition to the M100 system, an additional filter was attached to the first collection point prior to water passing through into the additional tank. This filter helps eliminate primary contaminants designed by WaterStep's to use disk filters for the effectiveness of organic substance removal. Once chlorine levels reach 3-5 ppm (parts per million) the water is safe and free of bacteria and contaminants, after testing the water for these precise levels the value will be switched on for direct household access. To better understand this system, I visited the site and observed the systems complete process from the original water source to the complete process of chlorination and conducted a focus group interview with members of the water committee.

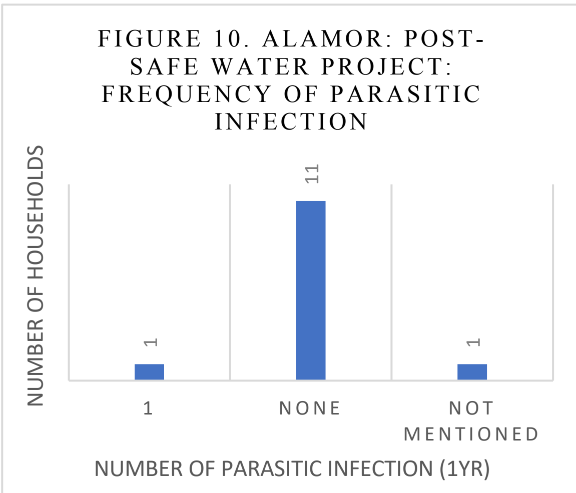
As this study area has had access to safe water for a year now 13 households in total were asked DALY and WTP surveys prior to safe water access. The analysis was completed after safe water access to analyze how one's access to safe water affects a household's life expectancy. Represented in Figure 9, prior to households' access to safe water all participants conveyed experiences of illness due to parasites with infections in households ranging from one to four

FIGURE 9. ALAMOR: PRE-SAFE WATER PROJECT: FREQUENCY OF PARASITE INFECTION



times every year mostly in younger children. In addition, diarrhea, stomach pain, skin irritation, and fever were among symptoms experienced along with the flu. 92% of respondents visited the hospital 2-4 times in one year and attributed their illness to the water used being contaminated along with the environment for their flu symptoms. As a result of these illnesses, 77% of respondents stated the average number of days unable to work or school was between 1-4 days per year, while others claimed illnesses kept them bedridden for 5-8 days. Prior to the clean water project, all households did not have piped water access and for water, access would walk to the river Amara la Florida once or twice every day to account for 2-4 hours spent daily on water collection. All families described the hardship of collecting water by foot or with a mule was tiring and they faced constant stress of never having enough. Also, the water gathered was only for drinking and cooking purposes which resulted in other activities using water directly from sources nearby. Every household except one had access to a latrine with the majority of facilities being outside with access to water and soap for handwashing nearby. One participant interviewed was also the teacher at the communities' school and stated of the 13 students attending all had missed some amount of school every year attributed to illness. The average age of respondents interviewed ranged from 40 years old and older with an average of 5-6 people living in each household although the focus group of 5 were not asked this question.

Post safe water implementation household responses drastically changed with regard to their health. On average 92% now live parasite-free, see Figure 10, and some families experience common sickness of flu, fever, and other environmental sicknesses. The number of visits to the hospital significantly decreased with 54% of households visiting once this year while 23% reported not going to the hospital since the system was installed. This reflected the number of days unable to work or attend school as 85% said they never miss a day due to sicknesses and of those who do only miss 1 day. All households pay $3.00 per month for their water and 69% receive 15 c3 per month while 31% receive 12-13 c3. All families interviewed agreed this was enough water for their family for all activities with some having extra water every month. When participants were asked how their lives have changed as a result of accessing safe water expressions of joy and eagerness were the tones of all respondents. "Our lives are better, happier, healthier, we don't have to walk hours to get water from the river and still not have enough…" (Interviewee 29, July 4, 2019). There have been significant improvements to family's health especially from not having continuous parasitic infections every year, a happier household, the elimination of stress related to water collection and never having enough. As a teacher in her community school expressed, "before the system children would miss at least one or more days sick, now school attendance is much higher and we have enough water" (Interviewee 33, July 4, 2019).



5.3 Healthcare Officials: Disease Prevalence in Rural Communities

Doctor's working in two different municipalities within my study area were interviewed. The doctor in El Arenal worked at a private hospital while the doctor in Chaquinal worked in a public hospital. The differences in these health facilities in Ecuador's health section is free service versus paid service. The private hospital in El Arenal requires a payment of $12.00 per person per visit to the facility and this will cover consultation, treatment, and medication if needed. This particular facility is open every day of the week from 8am-5pm and there is one doctor in the office with two nurses and one doctor in the field alternating shifts. The public hospital in Chaquinal is run by one doctor with accompanied nursing staff and opens from 8am-5pm with days in office operation from Monday, Wednesday, and Fridays and in field days on Tuesday and Thursdays. Both healthcare facilities operate in rural communities with small populations; therefore, there are no issues with long lines. On average both facilities estimated around 15 patients are seen in the center every day for various consultations and treatment. Of those 15 people around 3 people will have a parasitic infection. Therefore, by looking at the number of parasitic infections in one year this would equal 1,095 people infected with parasites out of 5,340 total patients seen in a year, representing 20% of all cases treated are due to parasites. When including cases of gastrointestinal, diarrhea and colon problems this can sometimes represent 5 out of 15 people seen each day, a total of 34% of all patients seen. Symptoms most commonly expressed by patients with these infections range from abnormal stomach behavior and bloating, excessive drooling when asleep, grinding teeth, stomach pain and an increased frequency of diarrhea and watery stool. In some cases, people might not experience any symptoms for days until the infections worsen. These infections are most common in children eight years old and younger as reported from the doctors.

Reasons for a higher number of cases relating to water-related illnesses in children can be attributed to the lack of handwashing after children use the bathroom, drinking water that is contaminated, consuming, and touching food without clean hands, lacking a resilient immune system with exposure to bacteria, and exposure to unsanitary conditions where parasites and bacteria can be found. While there are no current epidemics in either community there are problems with mosquitos particularly in wet season summer months (October to May) when excessive amounts of rainwater overflow waterways that lead to stagnant water pools, flooded pipes and overflown water tanks which are a breeding ground for mosquito larvae. The majority of cases seen daily are noncommunicable diseases such as diabetes, headache, and other ailments which represent that a larger percentage of the 15 patients visiting the hospitals. But, communicable diseases such as those water-related and influenza are quite rampant in rural communities and can cause serious repercussions for those infected and with continuous infection.

The most frequent water-related communicable disease found in both clinics are of the parasitic family; the roundworm (*Ascaris lumbricoldes*), giardia (*giardia lamdia/ giardia instestinalis*), entamuba hystolitica (*Entamoeba histolytica*), soil-transmitted helminth (*helmintos*) and various protozoa parasites. While there are many concerns with parasitic infections one of the most troubling is their communicable infectious status. The nature of these communicable diseases can be a huge burden for those infected due to the severity of the infection. As most cases of infections occur in children the impact of this illness can be long term causing anemia, malnutrition and intestinal and gastroenteritis symptoms in later years. The most common method for parasitic detection is a stool sample which is sent to the larger city of Alamor in the neighboring area where a medical facility can analyze stool samples. Once a parasite has been detected the most common treatment provided by these hospitals are; Albendazol, Tridazol, and Metronidazol. Doasge and days required for medication depend on the type of parasite, the severity of infection and patient's history. Most commonly in these rural location's doctors noted the reoccurrence of parasitic infections in families and the acceptance families have about the source of infection coming from contaminated water. The burden of disease in these communities is high and one's healthy life years are greatly adjusted from these diseases and the ongoing cycles of infection.

6.0 Discussion

Reference Appendix C for DALY formula explanation and significance in greater detail.

Disability-adjusted life year calculations were calculated for the communities within Loja Province based on data collected from interviews with households and doctors within each community. These calculations are not to be a representation of all study areas in my research or of the nation as a whole. DALYs were calculated based on the results of the most reoccurring diseases related to lack of access to safe water and proper sanitation services. These diseases are parasitic infections, specifically in the class of intestinal nematode infections which includes all helminth diseases. DALY calculations are used to understand the burden of disease these infections have on the loss of one's healthy life years due to illness and disability. Due to time restrictions and limited resources to access data on specific variables in the DALY equation, this data was supplemented by the WHO Global Burden of Disease (GBD) DALY 2004 Report, CDC parasitic infection incubation reports, and the Institute for Health Metrics and Equation (IHME) for data regarding life expectancy in Ecuador (WHO, 2018c, 2014a, 2014b; IHME; 2010).

Formula: DALY= YLL + YLD
Disability-Adjusted Life Years= years of life lost due to premature mortality + years of life lost due to disability for people living with the health condition or its consequences

YLL variables used and origin of information:
YLL= N (number of deaths) x L (standard life expectancy at age of death in years) (WHO,2018c)

The number of deaths in one year caused from intestinal nematode infections for Latin America statistics from WHO GBD 2004 Report was reported between 0-1 death (WHO, 2018c, 2014a, 2014b; IHME; 2010). The life expectancy at age of death in years could not be found and therefore is an undetermined variable. Life expectancy in Ecuador as of 2016 is 76.33 years (IHME, 2010). Data could not be gathered regarding the age of death from intestinal nematode infection cases. Therefore, an example of data provided by GBD Report with one person's death with an estimated age of death at 65 years old is calculated in the example scenario below.

YLD variables used and origin of information:
YLD+ I (number of incident cases in 1 year) x DW (disability weight) x L (average duration of case until remission or death (in 1 year) (WHO, 2018c)

The number of cases attributed to intestinal nematode infection were gathered from medical interviews to represent 1,095 cases in one year. The disability weight of 0.03 for intestinal nematode infections was gathered from GBD updated 2004 Report and a case study re-examining disability weight by Ock et al., (2016; WHO, 2014a, n.d.; PAHO, 2011; IHME, 2010). The average duration of case until remission (treatment) was calculated using CDC incubation and duration of disease information for each intestinal nematode infection included in my study, which comprised of the parasites of soil-transmitted helminths; roundworm, whipworm and hookworms (Weatherhead et al., 2017; PAHO, 2011). Based on each parasites duration of infection divided by the total number of parasites under comparison; an average of 3.5 weeks in 1 year was calculated (CDC, 2019). Referencing the average number of times households reported visiting the hospital specifically for parasitic infections was given the value of 3 times a year as this is a downscaled estimation. Therefore, 3.5 was multiplied by 3 to reach 10.5 weeks which represents the number of weeks in one year someone experienced symptoms from nematode infections. These calculations are all a low estimation using the lowest of the range to ensure calculations are not overplayed from my results. The frequency of DALY estimations for parasitic infections being downplayed is a trend within reports that will be explained further in Appendix C Section 2 and why DALYs cannot be used to solely represent the total healthy years impacted by these diseases (King, 2015).

This data was only gathered from the Loja Province (3 of the 4 communities studied) and is a representation from the communities visited in my study area. This is not a nationwide representation as Ecuador does not have a calculated DALY for parasitic infection to be compared to.

DALY Calculation 1:

$$YLL = 0 \times (76.33 - X) \qquad YLD = 1{,}095 \times 0.03 \times 0.2019$$
$$YLL = 0 \qquad YLD = 6.632$$

$$DALY = 0 + 6.632$$
$$DALY = 6.632 \text{ healthy life years (lost)}$$

Therefore, a DALY of 6.632 expresses the number of healthy life years lost in one's life due to the consequences of parasitic infections impacting their life in terms of health implications, ability to perform to their highest ability, ability to maintain healthy nutrition and functions and their physiological happiness. In the case when an individual lives until life expectancy of 76.33 years in Ecuador but has suffered reoccurring parasitic infection with an average of 3 infections per year out of their total lifespan they have lost over 6 years disabled with infection. This data can also be represented by looking at someone's total expected lifespan of 76.33 years, with a DALY of 6.632 this means that 8% of someone's total life was spent suffering (disabled) from intestinal nematode infections.

In the case where an individual does not live to 76.33 years old and dies for example at 65 years old due to implications from parasitic infections attributed to the number of infections but also the long-term effects from re-infection to parasitic diseases, which are not represented in the current DALY, an example of this scenario is shown below referenced only as an example not based on age of death due to infection, as this data for the region could not be found. The WHO GBD 2004 Report did record an estimated 0 to 1 death per year attributed to intestinal nematode infection in Latin America, which will be used to represent the one death (WHO, 2018b, 2018c, 2016d, n.d.; PAHO, 2011; IHME, 2010). All other excluding age of death remains constant from example 1 as resource supported data.

DALY Calculation 2: Example scenario:

YLL= 1 x (76.33-65) *YLD= 6.632 (unchanged)*
YLL= 11.33

DALY= 11.33 + 6.632
DALY= 17.962 healthy life years (lost)

The results from this example where 1 person of the 1,095 cases died at the age of 65, 11.33 years earlier than their full potential which represents a DALY of 17.96 healthy life years that were impacted by the burden of parasite disease. Parasitic infections especially those of the intestinal nematode infections are neglected tropical diseases that are often given little funding in public health control prevention and research yet 1 in 6 people worldwide are disabled in some form from the burden of this disease (PAHO, 2011; Awasthi and Bundy, 2003; Jensen, n.d.; WHO, n.d.). In comparison to the first DALY score with no lives lost due to infection, with one life lost 11 years prior to expected healthy life expectancy, this DALY reflected a disease burden of 23.5% of one's total life taken by intestinal nematode infections through morbidity and early mortality.

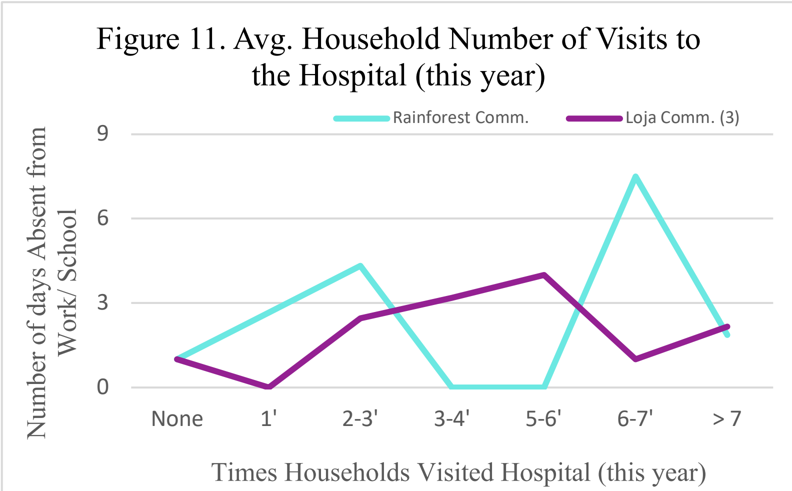
6.0.1 The Impact of Parasitic Diseases Long-term

In today's current climate it is estimated that one-third of almost 3 billion people that live in the developing regions of sub-Saharan Africa, Asia, and the Americas who live off less than $2.00 USD per day, are infected with one or more helminth infection (PAHO, 2011; Hotez et al., 2008; Awasthi and Bundy, 2003; WHO, n.d.). Helminthiases are known to be the diseases of poverty due to their frequency in cases of those living in situations of unimproved sanitation services, access to contaminated water, poor health and hygiene, crowded environments and contact with contaminated soil and sources of infection (King, 2015; PAHO, 2011; Hotez et al., 2008). As there are multiple parasitic infections that are classified under these infections this means that thousands of people can be living with several different species of parasitic worm and fall ill to the presence of multiple parasites in the same host, also referred to as poly-parasitized (Weatherhead et al., 2017; King, 2015; Hotez et al., 2008). While different parasitic infections have a preferred age-group associated with most frequent causes of infection the majority of parasitic disease burdens is held on school-aged children and pre-school children. The repercussions of these multiple infections and occurrences result inexperienced growth stunting, diminished physical fitness and impaired memory and cognition (Weatherhead et al., 2017; WHO, 2017a, 2017b, n.d.; King, 2015; Hotez et al., 2008). When coupled by the physical burden of infection and secondary health effects this leads to impair childhood educational performance, reduction of school attendance and the observation that hookworms and those similar reduce future wage-earning capacity of those continuously infected (Weatherhead et al., 2017; WHO, 2017a; King, 2015; Hotez et al., 2008).

Therefore, the DALY of one's healthy life years lost to parasitic infection do not show the future long-term health consequences, wage-earning employment, mental health and the many other health consequences resulting from parasitic infection (King, 2015; WHO, 2014b, 2006, n.d.). As shown from interviews with households the burden of disease has been reflected on the average trips to the hospital for treatment, the number of days unable to attend school or work and the constant stress of using contaminated sources and exposure to the direct source of reinfection.

6.1 Regional Comparison Analysis

In total 50 households in the Loja Province were interviewed and 20 households in the Orellana Province. The results from these two regions share similarities and also stark differences. Similarities were shared between the frequency of symptoms and the most present ones experienced. These ranged from diarrhea, parasites, stomachache, fever, vomiting, and others, which includes flu. This speaks largely to the living circumstances each community had and the similarities they shared with lack of access to safely managed sanitation systems and access to safe water. Therefore, the presence of parasitic diseases specifically those in the helminth family can thrive in these environments spreading through contaminated water, soil and the lack of proper hygiene services. What is different about their access to services is 80% of households in the rainforest did not have a latrine and therefore practiced open defecation compared to only 6% of households in Loja not having access to a latrine. Due to suitable conditions for the spread of disease and infection, a correlation was drawn between the number of times households visited the hospital this year and the number of days they were unable to work or attend school. Predictions were that as the number of visits to the hospital increase, the number of days unable to work or attend school would also increase.



The data shown in Figure 11, represents households in both rainforest community and three communities in Loja's average visits to the hospital this year, with the exception that data from Alamor *parroquia* was used pre-safe water system from one year prior to better understand the health implications before safe water access. On average, there is a gradual increase in a number of visits to the hospital and the number of days unable to work or attend school. Some factors affecting higher averages stem from children under pre-school age unable to be accounted for, who are most affected by the burden of disease.

In addition, a key difference amongst these regions is the source of water and the quantity of water used for drinking and cooking along with other activities. As mentioned previously, the rainforest community only has rainwater tanks due to the oil spill and their compensation for the damages to the river and ecosystems. Therefore, over 90% of households here used rainwater when accessible for drinking and cooking activities only and used the river or a brook for other water uses. This is different from the Loja region that relies 100% on mountain streams or rivers whose origin stems from the mountains for water sources and almost no references of using rainwater for consumption purposes. Shown in Figure 12, 67% of all households in the rainforest region use less than 5 cubic meter (c3) of water a month, with the majority of households consuming only 1.3 c3. With the average family in the rainforest around 5 people, this means each person drinks less than 0.26 c3 a month, far below healthy levels of water consumption.

Figure 12. Avg. Quantity of Water Used Monthly (cubic meters c3) Rainforest (20 households)

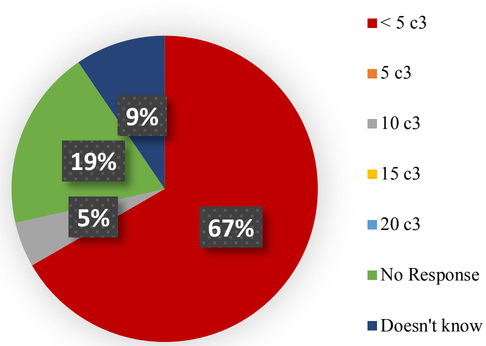
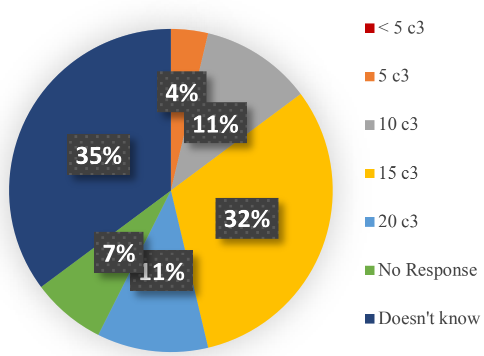


Figure 13. Avg. Quantity of Water Used Monthly (cubic meters c3) Loja (50 households)



In the Loja region, represented in Figure 13, families that had water meters which were all but one *parroquia* received around 15 c3 and most said this was plenty of water. The community that did not have water meters did not know their quantities but usually said they were without water from 1-3 hours every day, also a concern for one's health lacking access to water. As a result of these water differences, it is reflected in how much households currently pay for water monthly. While all households in the rainforest community do not pay for water and do not have any piped access, Loja region households on average pay between $2.00-3.50 USD. The sustainability and WTP analysis of each community studied cannot be a reflection alone of the payment's households can pay but rather needs to be compared to other basic services households pay for to determine if a project requiring $3.00 or similar can be sustained in the community.

6.2 WTP Value Based on Basic Services

Another key aspect of this research was to understand how much households were willing to pay for access to clean water services based off their current access to water, health issues stemming from unsafe water, and their basic service payments additionally. Information in reference to the average income and household payment for basic services was gathered through Grupo Social FEPP staff who live and work in the Loja region, WaterStep associated personal working in Orellana region and acquaintances in Coca city within the province, and through Ecuador's 2010 census data. Table 1 below includes one worker from each large city in the region and also one agricultural worker in the rural *parroquias* to represent differences and basic service payments along with the percentage each service accounts for out of the total annual income. Additional information about each regions workforce sector and access to basic services are represented in in Appendix D Tables three and four.

Table 1: Loja and Orellana Provinces Household Payment for Basic Services

Loja Province

$ USD		PP	H	H	H	H	
1 yr.	Avg. Income	School	Water	Electricity	Food & Other	Clothing	Total Expenses
Agr. Sector (*Canton* Puyango)	$1,200-1,800	$150.00 12.5%	$24.00 2%	$70.00 5.8%	$400.00 33%	$90.00 7.5%	$414.00 34.5%
Business Sector (Loja city)	$ 8,400	$94.00 1.1%	$204.00 2.4%	$144.00 1.7%	$1,600 19.0%	$520.00 6.1%	$1,362 16.2%

Orellana Province

$ USD		PP	H	H	H	H	
1 yr.	Avg. Income	School	Water	Electricity	Food & Other	Clothing	Total Expenses
Local Gov't official (Coca city)	$12,000	$200.00 1.6%	$300.00 2.5%	$360.00 3.0%	$8,064 67.2%	$1,000 8.3%	$3,876 32.3%
Agr. Sector (*Canton* Aguarico)	$4,500-6,000	Subsidized by Gov't	No Payment 0%	$60-84.00 1.3%	$1,200 26.6%	$540.00 12.0%	$1,800 40%

Key: PP= per person H=household

This data represents the differences in average yearly income and payments for basic services in the two different regions. Noticeably household expenses in Orellana region are much higher due to all services and necessities incurring river transportation costs to reach the far-removed communities such as those in *Canton* Aguarico. In addition, the cost of living in the Orellana region is more expensive as a result of the oil companies and their constant work and presence in the region. In both provinces, household expenses and cost of living in comparison to those in *Canton* Puyango and *Canton* Aguarico as these *parroquias* within these districts encompassed communities within my study area and are in different stages of safe water access projects.

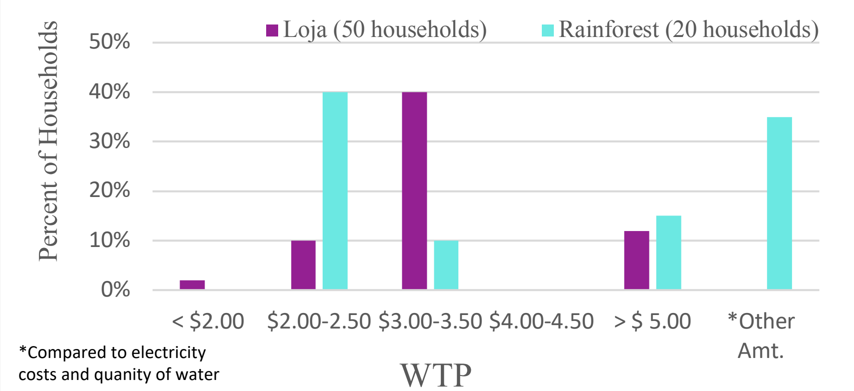
Based on the data presented in Table 1, conclusions can be drawn that the sustainable projects safe water system in which Grupo Social FEPP operates on using water payments of $3.00 per household per month to gain access to piped clean water would be suitable for other water projects in the Loja region. This is because households already pay around $2.00 per month, 2% of their yearly income for water which is not of sufficient quantity and free of contamination. Therefore, like most communities in the *parroquia* stated they would be willing to pay a minimum of $3.00 for safe water services with some estimating higher prices this would raise their year's payment for water services to a total of $36.00. In return for a difference of a $12.00 increase, more time can be directed towards work, school attendance, and healthier livelihoods in wage-earning jobs as a result of gained access to safe water. While public healthcare in Ecuador is free the burden of parasitic diseases has cost people healthy life years and lifelong consequences in both monetary and non-monetary expenses.

In comparison, Alta Florencia community does not currently pay for water services and although a DALY for the area was not calculated it can be estimated that their loss of healthy life years is of similar value or higher than those in Loja due to their use of the contaminated Napo River, their lack of access to accessible health services and other contamination and environmental costs in the region. While the majority of participants stated their WTP was between $2.50-3.00 which would be an ideal price for the maintenance of the system, the costs of $32.00 a year for access to safe water added to current basic service payments may be a shock to some households as their currently payments are 0% of total basic payments, to increase to 3% of their annual income for water payments might be beyond some household's ability to pay. As one woman interviewed in the community stated,

"… maybe I will sell my chickens but I have to pay for water, the lights are good for the children because now they can do their homework at night so we need those…We want the water if we have to pay what else can we do?" (Interviewee 71, June 10, 2019).

The comparison between these two regions was reflected in their willingness to pay for water services based on basic service payments, water access currently and current payment pay for water services has been represented in Figure 14. This Figure also speaks to the difference in willingness to pay and ability to pay. While water is a vital source of survival and people would pay high prices for access their ability to pay for that water might be lower than their willingness. A project for the Alta Florencia community might best be suited with initial payments of $2.00 per household per month as reflected by the households interviewed

Figure 14. Avg. WTP for Access to Safe Water Project in Both Regions



and their ability to pay. A large percentage of households compared their WTP to electricity prices and agreed both were essential but the quote referenced above reflects the ability to pay for electricity and now water services might cause strain to families and as a result they sell more goods or cut payment for other services to afford safe water, as a result this is not a sustainable project. The success of a project can only be measured if it is being used, while most people want to “hit the ground running” that is not the best method to ensure the sustainability of a system such as payments for safe water. A gradual transitional step to introduce payment for piped safe water services to ensure no single household is cutting payments from other basic services to pay for water or deciding they cannot afford monthly water payments continuously and abandon their service is to reference their ability to pay factored against their willingness to pay. Safe water systems only work to improve health when they are in continuous use and not selectively rationed. For further explanation on introducing payment to WASH services that have been used by organizations included in the UNICEF and WHO Joint Monitoring Program Report can be found in Appendix E (2019).

6.3 Climate Change Impacts on Parasitic Vectors and their Environment

The denial surrounding the effects of climate change can no longer be debated as worldwide impacts are being experienced in different avenues. Countries are witnessing events of increased floods and precipitation, others suffer from water shortages due to prolonged dry seasons, natural disasters strike regions harder and in unpredictable patterns, sea-level rise, elevated water temperatures, and pH levels left coral reefs bleached and devastated, increased levels of air pollution contribute to a higher percentage of non-communicable deaths in elderly and children, and the list goes on (WHO, 2018b; UNICEF, 2016). What all these climates influenced changes to have in common is they can be seen, felt in real-time, recorded or broadcasted for others to view, but what about the indirect consequences that are not easily seen? The consequences such as an increase or change in endemic regions of parasitic diseases? Migration, informal settlements, populations' shifts and growth, and ecological disturbances are clear paths for disease transmission as humans and animals become the host to diseases or travel through new regions with an infection and contaminate people via a direct transmission (WHO and WMO, 2012).

Parasitic infections such as giardiasis, cryptosporidiosis, amebiasis, and toxoplasmosis all can be transmitted through contaminated drinking water (WHO, 2012). As water resources become more scarce decreasing in both quantity and quality due to the strain of climate change this also puts humans and animals in closer spaces resulting in water sources to be shared (Short et al., 2017; WHO and WMO, 2012; Ben et al., 2011; Hunter, 2003). Animals carry additional diseases that can directly be transmitted via contaminated water to humans and result in serious burdens of disease. Throughout the communities in my study area numerous believe sources of illness traced back to animals sharing their water sources specifically the rivers and animals not only drinking the water but also open channels of water run through their pastures with feces, fertilizer and other contaminants wash into the water transmitted directly to households (Short et al., 2017; WHO and WMO, 2012; Ben et al., 2011; Hunter, 2003). In one community where the majority does not have access to latrines and use, the environment or river to relieve themselves, this is another direct form of contamination and spread of disease as one interviewee explained

"…I go to the bathroom in the river and my neighbors to my right than drink water from the river just meters away, and my neighbor to the left goes to the bathroom in the river and that goes directly into the water I drink from the river…" (Interviewee 71, June 10, 2019).

Anthropogenic climate change has increased greenhouse gas (GHG) emissions which have led to an increase in temperatures and a change in weather patterns which indirectly impacts the spatial patterns of disease vectors and human populations (Short et al., 2017; WHO and WMO, 2012; Ben et al., 2011; Hunter, 2003). Increased temperatures enable the development of arthropod vectors that carry parasitic organisms and the parasite themselves (Short et al., 2017; WHO and WMO, 2012; Ben et al., 2011; Hunter, 2003). In addition, a warmer climate is favorable to expand the range of reservoir hosts, vector abundance, biting and survival rates and parasitic transmission rates of vectors (Short et al., 2017). Helminth diseases such as hookworm, roundworm, and whipworm are the leading parasitic infections reported by both doctors in my study, are microscopic parasites that interact directly with their environment due to part of their life cycle which occurs outside the host in the soil (Short et al., 2017; WHO, 2016d, 2016e; Cartelle et al., 2015). Higher temperatures due to climate change have the ability to alter certain soil components which create faster larvae development and development within the eggs of hookworms, as a result this decreases their time period of growth and increases their lifecycle of infectivity with human hosts (Short et al., 2017; WHO and WMO, 2012). Also, increased humidity levels increase the larval survival in soil along with increased moisture from flood events in soils further enable growth and productivity of these infections (Short et al., 2017; Cartelle et al., 2015; WHO and WMO, 2012).

Parasitic diseases such as those found in Ecuador and within my study are most commonly found in environments that lack access to safely managed water and sanitation systems which hosts breeding grounds and direct access to human contact for infection (Cartelle et al., 2015; PAHO, n.d.). Climate change has increased periods of drought, which puts increased stress on water sources, which result in fewer participants that practice proper hygiene which increases their risk of exacerbating the prevalence of infection. Flood events also encourage parasitic growth and through favorable soil conditions, flooded sanitation systems, waterways mixed with contaminants and stagnant water sources all are conditions parasitic diseases need for increased transmission and infection to humans and animals (Short et al., 2017; Cartelle et al., 2015; Ben et al., 2011; Hunter, 2003). These infections alone cause significant health burdens and impact the lives of all in its grasp. With increased temperatures events which Ecuador is not exempt from this will affect the life cycles of parasites, creating an environment with a higher presence of parasitic organisms and its ability to expand to regions that once were unsuitable for parasitic diseases now suitable (Short et al., 2017; Cartelle et al., 2015; Ben et al., 2011; Hunter, 2003).

While the burden of disease physically disables one's health and affects their overall healthy life years it also promotes a positive feedback loop of poverty and economic stagnation in communities affected which creates a decline in overall quality of life (WHO, 2018b, 2018c; Short et al., 2017; WHO and WMO, 2017; Jensen, n.d.; WHO, n.d.). Poverty traps are often a result of high presence of disease and infection coupled with less than suitable living conditions and the constant cycle of illness, recontamination and the impact this has on one's ability to participate in wage-earning jobs, school, and building up improved water, sanitation and hygiene service access (WHO, 2018a, 2018b, 2016b, 2016d, n.d.; Short et al., 2017). The debilitating impacts parasitic diseases have on communities prevent productivity and advancement due to the loss of millions of workdays and the subsequent billions of dollars in economic growth each year (WHO, 2018b, 2018c, 2016b, n.d.; Short et al., 2017). Regions that already bear the burden of parasitic diseases are only expected to experience increases in disease presence and as a result, increased population disabled by these infections in the face of climate change.

7.0 Conclusions and Recommendations

Access to safe drinking water, sanitation, and hygiene services are crucial for human health and well-being (WHO, 2018a, 2016e). Drinking unsafe water not only impairs one's physical health through exposure to parasitic diseases, diarrheal illness and water-related diseases that host vectors but also contribute to a decline in wage-earning livelihoods, school attendance, and healthy mental beings. We now know for cases of parasitic infection the duration of infection is not the only burden of its illness but also the significant long-term health consequences and reoccurrence of cases impairs one's ability to improve their well-being and live a long-expected life (King, 2015).

Conclusions can be drawn from both primary and secondary research that rural communities in Ecuador still lack access to safely managed WASH services (UNICEF and WHO, 2019). While efforts have been put forth to gain access to these services in response to SDG Target "ensure availability and sustainable management of water for all," there are still large strides of development ahead to increase communities' access to these services (UN, 2018, 2016). WTP information is key to understand the sustainability of a project in its beginning stages and the value communities attach to pay for clean water access. Without these questions, a project cannot be guaranteed long-term success if payments for water services are higher than households are able to afford and comparable to additional basic services. In addition, it is important to understand the complexities and differences each region has and their specific needs and concerns. For example, the community studied in the Amazon almost all households did not have access to latrine services and received water either directly from the source or through rainwater collection tanks. In addition, the circumstances of oil contamination in the region and the use of the Napo River for drinking water and other water-related services are very different from those in Loja communities. Whereas in Loja communities studied the majority of households had access to basic latrine services but lacked access to safely managed water services. Most communities did have access to piped water on their premise originating from mountain streams but did not have consistent water or enough, a point shared in both regions. As a result, not all WASH projects can be universally applied and replicated due to the factors that attribute to communities' current access and use of water services and the development needed as key steps for achievement.

The success of calculating a DALY in rural communities studied in the Loja region highlights the burden of parasitic diseases on one's healthy life years. This value speaks to the number of continuous parasitic infection, visits to the hospital and time unable to participate in wage-earning jobs or to attend school (WHO, 2018c, 2017a, 2016d, n.d.). Although a DALY has a high understatement value placed on parasitic diseases such as those in the intestinal nematode family this value can still be used for non-health personnel to understand the cost physically and monetary value unsafe water has on populations. There has been a volume of research that stresses the correlation between climate change and the spread and distribution of parasitic diseases and their associated vectors (Short et al., 2017; WHO, 2015; WHO and WMO, 2012). The significance of this relationship will not only directly affect populations globally but also indirectly affects the human quality of life. The nature of parasitic diseases allows them to rely on environmental conditions that are most suitable for their growth and transmission, with climate change these conditions are most favorable for parasites to infect a larger number of people through emergence with stronger infection rates and reemergence in areas now suitable for vectors (Short et al., 2017). Also, the indirect effects parasitic diseases have on human populations reaches all sectors of livelihoods with the ability to infect and destroy agricultural crops, livestock, and other livelihood activities along which impacts community's advancement and development impacting economic growth (Short et al., 2017; King, 2015; WHO and WMO, 2012). It is critical that in the wake of climate change suitable environments for parasitic growth and infection are growing in range, therefore, to improve circumstances that foster the growth and reproduction of these diseases, mitigation strategies such updated WASH services and educational training on the common transmission of disease can be brought to communities who are in most need to receive these services and be rid of the burden of disease.

The improvement of WASH services towards safely managed drinking water and sanitation services with regulated piped water connections and sewer connections with treatment along with improved hygiene facilities can drastically improve the health of communities through reduced transmission routes for parasitic diseases and exposure to contaminants that lead to diarrheal infection and other water-related illness (WHO, 2018a, 2017b, 2016d, 2016f). Access to WASH services is also a critical aspect of equity and essential element for households to achieve quality live standards climbing out of poverty gaps and unsuitable circumstances. As recognized by the UN, access to safe water and sanitation services is a fundamental human right and are cost-effective benefits for countries (WHO, 2018a, 2017b, 2016d, 2016f). This is because the economic returns of improved WASH services continue to be high with benefits of nearly $5.00 USD for every dollar invested in improved services due to reduced medical costs associated with vaccine and nationwide prevention treatments, higher attendance in jobs and school and decreased long-term ailments and health costs causing disability or premature mortality (WHO, 2018a, 2016d, 2016f).

It is important to recognize the work organizations such as Grupo Social FEPP and WaterStep who work in these sectors to implement projects in rural communities that lack access to safe water services, sanitation systems and similar. Local actors who work conjointly with international organizations allow for increased effective communication on the cost-effective, positive economic and health benefits resulting from improved WASH services. In addition, it is projects like this that have the ability to contribute field-data and highlight WHO and similar organizations public health reports, and programs that provide the information required to bridge together gaps to understand current circumstances of WASH profiles and speak to governments and stakeholders to work towards progress and development in this sector (WHO, 2018a, 2017b, 2016d, 2016f). The effects of climate change will only continue to impact pre-existing WASH infrastructure, populations vulnerability to disease outbreaks and countries economic and natural resources. This is the time for global efforts to collaborate on research and development in the WASH sector to improve all populations accessibility to these improved sources to ensure a healthier life, resilience and the chance for communities to build upon their adversities to achieve a higher standard of life for themselves and generations to come.

References

Altizer, S., Ostfeld, R. S., Johnson, P. T. ., Kutz, S., & Harvell, D. C. (2013). Climate Change and Infectious Diseases: From Evidence to a Predictive Framework. *American Association for the Advancement of Science*, *341*, 514–519.

Anderson, R., Barnum, H., & World Bank. (1993). *Disease Control Priorities in Developing Countries*. (D. Jamison, H. Mosley, A. Measham, & J. L. Bobadilla, Eds.). New York: Oxford University Press.

Awasthi, S., Bundy, D. A. P., & Savioli, L. (2003). Helminthic infections. *BMJ (Clinical Research Ed.)*, *327*(7412), 431–433.

Ayers, J. M., & Huq, S. (2009). Supporting Adaptation to Climate Change: What Role for Official Development Assistance? *Development Policy Review*, *27*(6), 675–692.

Bartram, J. (2008). Flowing away: water and health opportunities. *Bulletin of the World Health Organization*, *86*(1), 2. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18235877

Buytaert, W., Vuille, M., Dewulf, A., Urrutia, R., Karmalkar, A., & Célleri, R. (2010). Hydrology and Earth System Sciences Uncertainties in climate change projections and regional downscaling in the tropical Andes: implications for water resources management. *Hydrol. Earth Syst. Sci*, *14*, 1247–1258.

Callan, S., & Thomas, J. (2012). Defining Water Quality. In E. Joyner, J. Sabatino, & E. Beiting-Lipps (Eds.), *Environmental Economics & Management Theory, Policy, and Applications* (6th ed., pp. 330–350). Manson, Ohio: South-Western Cengage Learning.

Cartelle Gestal, M., Holban, A. M., Escalante, S., & Cevallos, M. (2015). Epidemiology of Tropical Neglected Diseases in Ecuador in the Last 20 Years. *Plos One* , *10*(9), 12.

CDC. (2019). Parasitic Worm Biology and Duration. Center for Disease Control and Prevention. Atlanta. Retrieved from https://www.cdc.gov/parasites/hookworm/biology.html

CDC. (2013). *Introduction to NCD Epidemiology*. Center for Disease Control and Prevention. Atlanta. Retrieved from https://www.cdc.gov/globalhealth/healthprotection/fetp/training_modules/1/Intro-to-Epi_PPT__Final_09252013.pdf

CDC. (2010). Definitions for Consideration. Retrieved from https://www.cdc.gov/tb/programs/laws/menu/definitions.htm

CDC. (n.d.). Parasites. Center for Disease Control and Prevention. Atlanta. Retrieved from https://www.cdc.gov/parasites/about.html

CIA. (2019). Central Intelligence Agency South America: Ecuador. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/ec.html

DeBose, K. (2017). Research Methods Guide: Interview Research. Retrieved from https://guides.lib.vt.edu/researchmethods/interviews

Ebi, K. L. (2008). Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. *Globalization and Health*, *4*(1), 9.

FAO. (2000). *Applications of the contingent valuation method in developing countries*. Food and Agriculture Organization of the United Nations. Rome. Retrieved from http://www.fao.org/3/X8955E/x8955e00.htm

FAO. (n.d.). Applications of the contingent valuation method in developing countries. Food and Agriculture Organization of the United Nations. Rome. Retrieved from http://www.fao.org/3/X8955E/x8955e03.htm

Gassert, F., Reig, P., Luck, M., & Landis, M. (2015). Aqueduct Global Maps 2.1 Indicators. Retrieved from https://www.wri.org/publication/aqueduct-global-maps-21-indicators

Gersovitz, M., & Hammer, J. S. (2003). Infectious Diseases, Public Policy, and the Marriage of Economics and Epidemiology. *The World Bank Research Observer*, *18*(2), 129–157.

Habitat. (1995). Guidelines for Assessing Effecting Demand of Communities for Environmental Infrastructure. In *Community-Based Environmental Management Information System (CEMIS)* (p. 144). Community Development Library.

Hence, J. (2013). 11,000 barrels of oil spill into the Coca River in the Amazon. Mongabay Non-Profit Conservation and Environmental News Platform. Retrieved from https://news.mongabay.com/2013/06/11000-barrels-of-oil-spill-into-the-coca-river-in-the-amazon/</

Hotez, P. J., Brindley, P. J., Bethony, J. M., King, C. H., Pearce, E. J., & Jacobson, J. (2008). Helminth infections: the great neglected tropical diseases. *The Journal of Clinical Investigation*, 118(4), 1311-21.

IHME. (2010). Global Burden of Diseases, Injuries, and Risk Factors Study 2010. Washington. Retrieved from http://www.healthmetricsandevaluation.org

INEC. (2010). *Census Report: Poblición y Drmografía*. Instituto Nacional de Estadítica y Censos. Quito.

Johns, T. C., Gregory, J. M., Stott, P. A., & Mitchell, J. F. B. (2001). Correlations between patterns of 19th and 20th-century surface temperature change and HadCM2 Climate Model ensembles. *Geophysical Research Letters*, *28*(6), 1007–1010.

King, C. H. (2015). Health metrics for helminth infections. *Acta Tropica*, *141*(Pt B), 150–160.

Motlaleng, M., & Thukuza, A. (2011). *Households Willingness to Pay for Improved Water Quality and Reliability of Supply in Chobe Ward, Maun*. Botswana.

N.A. (2019). City Population Database Ecuador: Provinces, Major Cities, and Towns - Population Statistics, Maps, Charts. Retrieved from https://www.citypopulation.de/Ecuador-Cities.html

N.A. (2018). Climate Modeling – Geophysical Fluid Dynamics Laboratory. Retrieved from https://www.gfdl.noaa.gov/climate-modeling/

N.A. (2014). City Population Database. Population Statistics, Loja (Province, Ecuador)- Charts, Map and Location. Retrieved from https://www.citypopulation.de/php/ecuador-parish-admin.php?adm1id=11

Norte Dame Global Adaptation Initiative. (n.d.). *Country Index: Ecuador Adaptation and Vulnerability Report*. The University of Norte Dame. Indiana. Retrieved from https://gain.nd.edu/our-work/country-index/

Pahl-Wostl, C., Arthington, A., Bogardi, J., Bunn, S. E., Hoff, H., Lebel, L., … Tsegai, D. (2013). Environmental flows and water governance: managing sustainable water uses. *Current Opinion in Environmental Sustainability*, *5*(3–4), 341–351.

PAHO. (2011). *Prevalence and intensity of infection of Soil-transmitted Helminths in Latin America and the Caribbean Countries*. Pan American Health Organization. Washington, D.C. Retrieved from www.paho.org.

PAHO. (n.d.). Neglected Infectious Diseases. Pan American Health Organization. Washington, D.C. Retrieved from https://www.paho.org/salud-en-las-americas-2017/?tag=dalys

Pats, J., Campbell- Lendrum, D., Holloway, T., & Tracey, F. H. (2005). Impact of Regional Climate Change on Human Health. *Nature Publishing Group*, *438*, 310–316.

Prüss-Üstün, A., Kay, D., Fewtrell, L., & Bartram, J. (2004). Unsafe Water, Sanitation and Hygiene. In M. Ezzati, A. Lopez, A. Rodgers, & C. Murray (Eds.), *Comparative Quantification of Health Risks* (pp. 1321–1350). World Health Organization. Geneva.

Reid, K. (2018). 2016 Ecuador earthquake. World Vision. The United Kingdom. Retrieved from https://www.worldvision.org/disaster-relief-news-stories/2016-ecuador-earthquake-facts

Rodó, X., Pascual, M., Doblas-Reyes, F. J., Gershunov, A., Stone, D. A., Giorgi, F., … Dobson, A. P. (2013). Climate change and infectious diseases: Can we meet the needs for better prediction? *Climatic Change*, *118*(3–4), 625–640

Romulo, C., Posner, S., Cousins, S., Fair, J., Bennett, D., Huber-Stearns, H., … McDonald, R. (2018). Global state and potential scope of investment in watershed services for large cities. *Nature Communications*, *9*(4375), 8.

Sengupta, A., & Polle, A. (1997). *Workshop on Willingness to Pay for Drinking Water Supply and Sanitation*. UNDP- World Bank Regional Water and Sanitation Group, South Asia. New Delhi.

Short, E. E., Caminade, C., & Thomas, B. N. (2017). Climate Change Contribution to the Emergence of Re-Emergence of Parasitic Diseases. *Infectious Diseases*, *10*.

Stern, N. (2014). *Stern Review: The Economics of Climate Change*. American Economic Review.

Stevenson, E., Greene, L., Maes, K., Ambelu, A., Tesfaye, Y., Rheingans, R., & Hadley, C. (2012). *Water insecurity in 3 dimensions: an anthropological perspective on water and women's psychosocial distress in Ethiopia*. Maryland.

Tussupova, K., Berndtsson, R., Bramryd, T., & Beisenova, R. (2015). *Investigating Willingness to Pay to Improve Water Supply Services: Application of Contingent Valuation Method*. Sweden.

Ulmer, A. (2018). Ecuador says reaches a partial deal with China over crude sales - Reuters. Reuters Business News. Retrieved from https://uk.reuters.com/article/uk-oil-ecuador-china/ecuador-says-reaches-partial-deal-w

UNEP. (2019). Better Sewage Treatment Critical for Human Health and Ecosystems | UN Environment. Retrieved from https://www.unenvironment.org/news

UNHCR. (2017). *Populations | Global Focus*. The United Nations Refugee Agency. Geneva. Retrieved from http://reporting.unhcr.org/population

UNICEF and WHO. (2019). *Joint Monitoring Program: Progress on household drinking water, sanitation and hygiene 2000-2017*. United Nations Children's Fund (UNICEF) and the World Health Organization (WHO). New York.

UN. (2018). Sustainable Development Goal 6. United Nations Sustainable Development Platform. New York. Retrieved from https://sustainabledevelopment.un.org/sdg6

UN. (2016). Transforming our world: the 2030 Agenda for Sustainable Development: Sustainable Development Knowledge Platform. United Nation. Sustainable Development Platform. New York. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld

UNDP. (n.d.). Ecuador | UNDP Climate Change Adaptation. United Nations Development Platform. New York. Retrieved from https://www.adaptation-undp.org/explore/south-america/ecuador

Urrutia, R., & Vuille, M. (2009). *Climate change projections for the tropical Andes using a regional climate model: Temperature and precipitation simulations for the end of the 21st century*. *Journal of Geophysical Research* (Vol. 114). John Wiley & Sons, Ltd.

Weatherhead, J. E., Hotez, P. J., & Mejia, R. (2017). The Global State of Helminth Control and Elimination in Children. *Pediatric Clinics of North America*, *64*(4), 867–877.

Whittington, D., Briscoe, J., & Mu, X. (1987). *Willingness to Pay for Water in Rural Areas: Methodological Approaches and an Application in Haiti*. Arlington, Virginia.

WHO. (2019). Soil-transmitted Helminth Infections. World Health Organization. Geneva. Retreived from https://www.who.int/en/news-room/fact-sheets/detail/soil-transmitted-helminth-infections

WHO. (2018a). *Water, Sanitation and Hygiene Strategy Report 2018-2025*. World Health Organization. Geneva. Retrieved from http://apps.who.int/bookorders

WHO. (2018b). Disease, injury, and causes of death regional estimates, 2004-2008. *World Health Organization*. Retrieved from https://www.who.int/healthinfo/global_burden_disease/estimates_regional_2004_

WHO. (2018c). Disability-adjusted life years (DALYs). World Health Organization. Geneva Retrieved from https://www.who.int/gho/mortality_burden_disease/daly_rates/

WHO. (2017a). *Soil-transmitted helminthiases Database Neglected Tropical Diseases*. World Health Organization. Geneva. Retrieved from http://apps.who.int/neglected_diseases/ntddata/sth/sth.html

WHO. (2017b). Vector-borne diseases. World Health Organization. Geneva. Retrieved from https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases

WHO. (2016a). What is the minimum quantity of water needed? World Health Organization. Geneva. Retrieved from https://www.who.int/water_sanitation_health/emergencies/qa/emergencies

WHO. (2016b). Intestinal worms. World Health Organization. Geneva. Retrieved from https://www.who.int/intestinal_worms/more/en/

WHO. (2016c). Access to piped water: Global Health Observatory (GHO) Data. World Health Organization. Geneva. Retrieved from https://www.who.int/gho/urbanhealth/environmental-risk-factors/safe_water/en/index1.html

WHO. (2016d). *Health Statistics and Information Services*. World Health Organization. Geneva. Retrieved from https://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html

WHO. (2016e). Water Sanitation and Hygiene. World Health Organization. Geneva. Retrieved from https://www.who.int/water_sanitation_health/en/

WHO. (2016f). Waterborne disease related to unsafe water and sanitation. World Health Organization. Geneva. Retrieved from http://www.who.int/sustainable-development/housing/health-risks/waterborne-disease/en/

WHO. (2015). Report on Global Surveillance of Epidemic-prone Infectious Diseases. World Health Organization. Geneva. Retrieved from https://www.who.int/csr/resources/publications/introduction/en/index5.html

WHO. (2014a). *Disability weights, discounting and age weighting of DALYs*. World Health Organization. Geneva. Retrieved from https://www.who.int/healthinfo/global_bur

WHO. (2014b). Quantifying Environmental Health Impacts. World Health Organization. Geneva. Retrieved from https://www.who.int/quantifying_ehimpacts/global/ebdcountgroup/en/

WHO. (2012). Amoebiasis. World Health Organization. Geneva. Retrieved from https://www.who.int/ith/diseases/amoebiasis/en/

WHO. (2006). *Preventive in human helminthiasis chemotherapy*. World Health Organization. Geneva. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/43545/9241547103_eng.pdf?sequence=1

WHO. (n.d.). *Burden of Disease: DALY*. World Health Organization. Geneva. Retrieved from https://www.who.int/healthinfo/global_burden_disease/GBD_report_2004update_part4.pdf

WHO and WMO. (2012). *Atlas of Health and Climate*. World Health Organization and World Meteorological Organization. Geneva. 1098 (58).

World Bank. (2015). *GDP per capita, PPP (current international $) | Data*. The World Bank Database. Washington D.C. Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

World Bank. (n.d.). *Ecuador: Water Supply, Sanitation and Hygiene*. The World Bank Database.Washington D.C. Retrieved from https://data.worldbank.org/indicator/SH.H2O.SMDW.ZS

Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*, *86*, 14–23. https://doi.org/10.1016/J.ENVINT.2015.09.007

Wu, X., Tian, H., Zhou, S., Chen, L., & Xu, B. (2014). Impact of global change on the transmission of human infectious diseases. *Science China Earth Sciences*, *57*(2), 189–203. https://doi.org/10.1007/s11430-013-4635-0

Appendices

Appendix A: Classification of Improved vs Unimproved Water and Sanitation Systems

The WHO and UNICEF report on water, sanitation, and hygiene services have defined and follow a global standard for the classification of improved water and sanitation services. These classifications are the baseline standards for research investigating countries access to these services and their level of access. Therefore, the classification of improved drinking water facilities is those having piped supplies from the sources of a tap/sink, piped access to water in an individual house, yard or premise and public stand posts (UNICEF and WHO, 2019; WHO, n.d.). For non-piped supplies that can be considered improved access to drinking water, this includes boreholes, protected wells, and springs, rainwater, packaged water and delivered water. Unimproved facilities are categorized by any non-piped supply that includes but not limited to unprotected wells, springs, and water retrieved directly from a waterway. Those that lack access to any service is defined as no access and can include those dependent on water vendors or water trucks and similar.

For water service to be considered safely managed drinking water services they should be accessible on households' premises, water should be available in sufficient quantity and of quality that is free of contamination (UNICEF and WHO, 2019). If the improved source of water does not meet any of these criteria and rather takes 30 minutes or less to collect than this is defined as a basic drinking water service. Limited water services are those that take more than 30 minutes to collect and do not meet the remaining requirements (UNICEF and WHO, 2019.).

To meet the Goal 6 under the Sustainable Development Goals to "ensure availability and sustainable management of water and sanitation services for all" safely managed sanitation services require a household to use an improved type of facility that is not communal, wastewater must be treated offsite through sewer lines and at wastewater treatment plants (United Nations, 2018; WHO, n.d). Septic tanks must be emptied and pit latrines and all excreta must be removed and treated off-site in facilities that are designed for fecal sludge treatment and excreta needs to be treated and disposed of in a site with appropriate leach fields or in latrines that are covered and left undisturbed when full (WHO and UNICEF, 2019). Half the world 's rural population and 32% of urban populations reported using improved sanitation facilities with on-site storage such as a flush or water pour-flush latrine connected to septic tanks and/or dry and wet latrines (WHO and UNICEF, 2019). Safely managed systems are improved pit latrines and septic tanks that ensure containment of fecal waste and provide treatment on-site. Issues surrounding systems which treat and store excreta on-site can face challenges with poor design, damaged systems due to floods or natural disasters (WHO and UNICEF, 2019). Communities still practicing open defecation are classified as those lacking all access to sanitation systems and as of 2015, 892 million people participated in this practice (United Nations, 2018).

Appendix B: WTP and DALY Surveys in English and Spanish and Consent Forms

Survey for Health Officials: Encuesta para autoridades sanitarias

1. How much does it cost to treat water-related illnesses?
   ¿Cuanto cuestan los tratamientos para enfermedades del agua?

2. What is the frequency of disease **outbreaks** and gastrointestinal cases?
   ¿Cual es la frecuencia de **brotes** de enfermedades y casos gastrointestinales?

   a. Infrequently – pocas veces b. Sometimes – a veces
   c. Often – a menudo d. Everyday -todos los días e. Never - nunca

3. What is people's level of access to health services?
   ¿Cual es el nivel de acceso a los servicios de salud?
   a. Anyone can come in –cualquiera que venga
   b. People need to have insurance – solo personas con seguros de salud
   c. Long lines to wait – largas filas de espera
   d. Short operational hours – tiempo limitdo de operaciones
   e. Lack of staff per patient volume – falta de personal para el volumen de pacientes

   Is there a hospital or speciality clinic?
   --Hay es el hospital o sub centros médicos?

4. How many people are seeking treatment here?
   ¿Cuantas personas son tratadas aqui?

   a. What is an estimated number of cases in the past (5) years that have been related to water-borne illnesses?
      ¿Cual es el número estimado de casos de enfermades de agua en los últimos 5 años?

   b. When people dont go to the clinic what happens?
      ¿Cuándo las personas no van al medico que pasa?

   c. Type of diseases?
      ¿Tipos de enfermadas?

- Parásitos
- Gastroenteritis à consecuencias
- Infecciones intestinales =anemia y desnutrición
- Diarrea
- Dermatitis (irritación de la piel)

Survey for Families: Encuesta por familias:
Survey for Disability Adjusted Life Years (DALY) for oldest female in households:

Encuesta para Años de Vida Ajustados por Discapacidad (AVAD) para las mujeres más mayores en la familia

1. How many times did someone in your household experience one of these illnesses?
   ¿Cuantas veces alguien de su familia tuvo alguna de estas enfermedades?
   a. Parásitos (bichos) b. Gastroenteritis c. infecciones intestinal
   d. Infecciones respitariorias e. dermatitis f. otra

(Not common Vocab)
E.coli- Escherichia coli b. Dysentery -Disenteria c. Salmonella - Salmonela

2. What were the symptoms of this illness?
   ¿Cuales son los síntomas de esta enfermedad?
   a. Diarrhea - diarrea b. Stomach pain- dolor de estomago
   c. Vomiting- vomito/naúseas d. Skin irritation – irritación de la piel
   e. Dehydration -deshidratación f. anemia- anemia
   g. loss of nutrition- desnutrición f. Other - otra

3. Where do you think you got the illness from?
   ¿Qué cree que lo enfermó?
   a. Comer b. el agua c. la calle d. la tierra e. letrina f. otra

4. How many times did someone in your household seek medical attention this year?
   ¿Con que frecuencia personas de su núcleo familiar fueron al medico este año?
   a. Once a week – una vez a la semana b. Once a month – una vez al mes c. Once a yr – una vez al año d. Other ____ - otra

5. How many days this year was this person unable to work or attend school due to illness?
   ¿Cuantos días en el año estuvo esta persona sin poder ir a la escuela o al trabajo por estar enfermo?
   a. uno a tres días b. cinco a diez días c. mas de diez días
6. How many times this year did someone in your household complain of stomach pains, diarrhea, or dehydration?
   ¿Cuantas veces en el año alguien de su nucleo familiar se quejo de dolor de estomago, diarrea o deshidratación?
   a. Infrequently – casi nunca b. Sometimes – a veces
   c. Often - a menudo/ frecuentemente d. Everyday – todos los dias e. Never- nunca

Survey for families: Encuesta por familias:
Survey for Households on Willingness to Pay (WTP):
Encuesta para familias con Disposición a Pagar (DAP)

Who is answering?
¿Quien responde?
Padre _____ Madre _____ Otra_____ …de la casa

¿Cuantos años tienes? _________ anos

\# of family members – ¿Cuantas de personas es en el núcleo familiar: ________

1. Do you have a piped water installment at home? (Y/N)
   ¿Ustedes tienen instalación de agua potable en la casa?
   a. ¿Afuera o adentro tu casa?
   b. Es de:
      i. Grifo
      ii. Cisterna
      iii. Un pozo de agua

2. Where does your drinking wáter come from?
   ¿De donde viene tomar agua por beber?
   a. Tanquero b. Rio/ pozos c. cascada d. las montanas
   e. Agua de llvuia f. agua de tubería comunal

3. Is the water treated? Yes or no?
   El agua es tratada o no?

4. Do you use the same wáter for cooking?
   ¿Tu usas mismo el agua por cocinar?

5. What are your daily sources of water for washing and bathing?
   ¿Cuál es su fuente diaria de agua para lavar y bañarse?

   a. River/ pond water – ríos/pozos b. Public well - Pozos públicos
   c. Rain water – Agua de lluvia d. Communal tap – agua de tubería comunal
   e. Private well – pozo privado

6. Do you have a latrine facility? (Y/N)
   ¿Tiene usted letrinas?
   a. ¿Afuera o adentre la casa?

7. Is there a bucket for handwashing your hands near the latrine?
   ¿Hay agua para lavarse los manos cerca de la letrina?
   a. Is there soap in the bathroom or near the water?
      ¿Hay jabón en el baño o cerca el agua?

8. Do you want a latrine for your house?
   ¿Tu quieres letrina por tu casa?

9. Estimate the amount of water used for drinking and cooking per day, and how much it costs?

¿Cual es la cantidad de agua estimada que usa para beber y cocinar por día y cuanto le cuesta? (por examplo…)

a. Un balde pequeño b. un balde mediano c. un balde grande d. un tanque e. en litros

10. How miuch does it cost for the amount of wáter per day or month?
    ¿Cuanto cuesta por la cantidad de agua por día o por mes?
    a. Costo US $_______________ por día o por mes

11. Do you have enough water for drinking and cooking for your daily needs? (Y/N)
    ¿Tiene usted suficiente agua para beber y cocinar para sus necesidades diarias? (s/n)

    a. Si no… ¿Por qué no tiene suficiente agua?
       i. No regular supply- no hay un suministro regular
       ii. Water is too expensive - el agua es muy carro
       iii. Need more wáter for household activities- neccistas mas agua para actividades casa
    b. How much more?
       Cuanto algo mas?
12. How do you manage your life with the shortage of water?
    ¿Como hacer para vivir con la escasez de agua?

13. If the coverage of safe water supply is expanded to include this area, would you be willing to get the installation? (Y/N)
    ¿Si la cobertura del suministro de agua potable con chloro se expandiera para esta zona, usted estaría interesado en tener una instalación? (s/n)

14. How much can you afford to pay for access to safe wáter a month? (cubic meters)
    ¿Cuánto puede pagar por tener acceso a agua potable al mes? En metro cubicos

    a. Willingness to pay for water consumption:
       Disposición a pagar por consume de agua: US$ _________

Spanish Consent Form:

<u>Investigacion para Agua Segura y Salud</u>

Date,
Encuesta para la investigación de mejora al acceso al agua segura y salud.

Las preguntas tienen como objetivo recolectar información sobre la situación de salud de las familias de la comunidad y conocer si están dispuestas a pagar por el consumo mensual de agua segura.

La información obtenida en esta encuesta será confidencial, se mantendrá en completa reserva los nombres de quienes participen. La participación es voluntaria.

Muchas gracias por su tiempo y colaboración.
Comunidad:
1. Comuna Kichwua Alta Florencia, *Parroquia* Nuevo Rocafuerte, *Canton* Aguarico, Provincia Orellana
2. El Arenal *Parroquia*, *Canton* Puyango, *Provencia* Loja
3. Alamor *Parroquia*, *Canton* Puyango, *Provencia* Loja
4. Chaquinal *Parroquia*, *Canton* Pindal, *Provencia* Loja

Firma: **Fecha/ tiempo:**

Appendix C: Disability Adjusted Life Years

Section 1: Disability-Adjusted Life Years (DALY) calculations

Health metrics are understood as numbers to quantify the impact of different diseases on one's personal health (King, 2015). The recent exploration to quantify disease impacts on human health come from the implementation of health economics in the evaluation of disease control initiatives brought forward by policymakers to improve the efficiency of health care investments (King, 2015). Therefore, one method of health assessment is the DALY, disability-adjusted life years. One DALY is a representation of one lost year of "healthy" life (WHO, 2018). The sum of DALY's across a population or burden of disease is a quantified measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age expected of that region and is free of diseases and disability (WHO, 2018). A DALY is calculated from the sum of years of life lost (YLL) due to premature mortality in the population and the years lost due to disability (YLD) for people living with that current health condition or disease (WHO, 2018). To separate the two variables within the equation, YLL is found from the number of deaths from that specific case multiplied times the standard life expectancy at age of death, represented in years. YLD is found from the multiplication of the number of incident cases, the disability weight given to that condition or disease and the average duration of the case until remission or death (WHO, 2014). The disability weight is a weight factor used to reflect the severity of the disease impacts on an individual based on a scale from 0 (perfect health) to 1 (dead). The original Global Burden of Disease Study (GBD) and WHO updates for years 2000-2004 also included several social value weights included in the calculation of the DALY for disease and injuries (WHO, 2014). Some of these social values included sex, age, and time discounting weights to determine the prevalence of the disease within a certain population such as the frequency in younger children or females for example (WHO, 2014). In GBD studies the updated 2004 report, a 0.302 disability weight was given to Intestinal nematode infections with a range from 0.211-0.407, with no discounting and age weights. Therefore, in my DALY calculations, I also used a 3% disability weight.

DALY formula: WHO, 2018c; WHO, 2016d; WHO, 2014a; WHO, n.d. data:
DALY= YLL + YLD

YLL= N x L	N=number of deaths L= standard life expectancy at age of death in years
YLD= I x DW x L	I= number of incident cases DW= disability weight L= average duration of case until remission or death (years)

Section 2: Importance and Faults

The importance of a DALY can be used to better determine the complete burden of disease outside or mortality statistics in different populations. A disease that causes high mortality can be compared to a disease that has no or low mortality but a higher disability impact. While the DALY can show a qualitative representation of the burden of disease its ability to represent this disease or disabling condition varies. Specifically, for parasitic infections the DALY value attached is often far lower than what the actual burden endured by one's healthy life years is. This is because the DALY's are assigned to one individual one disease or health condition which is usually their most disabling condition (King, 2015). It is determined then that any other health condition that may arise or latent disease complications stemming from the disease represented are treated as separate entities and accounted for in other calculations. The implications of separating long-term or secondary conditions from the base disease mean that it can minimize the perceived impact of communicable diseases and leads to a systematic underestimation of the score (King, 2015). For helminth infections, those included in the intestinal nematode infection family, which might not have chronic severely disabling symptoms but have frequent reoccurrence they are usually given a lower disability weight not accounting for the long-term impact on one's health or their frequency of infection (King, 2015). In addition, a disease impact on one's ability to earn income, attend a school or perform to their highest ability in good health or livelihood activities is not reflected in a DALY calculation which also lowers the value of INI DALYs value. As similar growth stunting, mild cognitive impairment caused by INI infections are not considered disabled and also excluded from the DALY score (ibid). As stated, while the DALY for INI can be used to demonstrate a quantified score of the burden of the disease there are many limitations of the DALY system specifically on parasitic infections such as those of NTDs which are overlooked in the disease burden assessments (ibid).

Appendix D: Statistical Data on Employment and Housing Census

Table 2: Orellana Province Census Data 2010

Orellana Province		2010 data			
Total Households:	41,040 individuals				
Sector of work	Self-employed	Private Sector	State, Municipality or Province Worker	Laborer	
	38.10%	21.80%	15.40%	11.70%	
Occupation	Farmer/ Worker	Elementary occupation*	Techniques & Professionals of middle level	Operators of facilities & machinery	
	49%	38%	15%	2440%	
Water Consumption	"As it comes"	Boil water	Buy purified water	Add chlorine to the water	Filter water
	42%	35%	16%	6%	1%
Living Structure	House	Ranch	Room	Hut	
	61%	17%	9%	6%	
Use of Basic Services	Public Electric Service	Without Electric Service and other	Telephone Service	Without Telephone Service	
	24,959	6,418	4,068	27,309	
	Public Water Network	Other Water Source	Trash Collection by cart	Another form	
	15,155	16,222	18,690	12,687	
	Connection to Public Sewage Network	Other Connection			
	8,485	22,892			

**Elementary Occupations (cleaning services, domestic work, street vendor, fishing, mining)

Table 3. Loja Provinces Census Data 2010

Loja Province 2010 data

Total Households: 155,308 individuals

The sector of work:	Self-employed	Private Sector	State, Municipality or Province Worker	Laborer	
	38%	20%	16%	13%	
Occupation:	Farmer/ Worker	Elementary occupation*	Service Worker/ Vender	Professional, Scientist & Intellectual	
	47%	26%	29%	25%	
Water Consumption	"As it comes"	Boil water	Buy purified water	Add chlorine to the water	Filter water
	58%	30%	9%	1%	1%
Living Structure	House	Apartment	Room	Hut	
	79%	8%	5%	5%	
Use of Basic Services	Public Electric Service	Without Electric Service and other	Telephone Service	Without Telephone Service	
	107,541	6,167	32,492	81,216	
	Public Water Network	Other Water Source	Trash Collection by cart	Another form	
	80,601	33,107	68,516	45,192	
	Connection to Public Sewage Network	Other Connection			
	N/A	N/A			

(Accessed from INEC, 2010).

Appendix E: The Importance of WTP in Reference to Basic Services

Introducing WASH Payments Accounting for Pre-existing Basic Service Payments

There are three key dimensions that shape how to measure and monitor the payment for WASH services that are equitable and adjusted to the economic group. First, explained as the amount a user pays for WASH services including the capital costs associated with new infrastructure, network connections ongoing maintenance, and related products such as containers, soap and the non-monetary cost accumulated during the time spent retrieving water or sanitation-related travel (UNICEF and WHO, 2019). These payments will depend on the factors they have to attribute towards and the existing infrastructure, service provider efficiency, market competition, level of corruption, number and type of water sources available to the user and the subsidy levels (UNICEF and WHO, 2019). Secondly, the spending power of the user is important to understand the income and wealth of the user and the household. This specifically looks at the assets, property and payments along with accumulated savings. This encompasses all interests that make the user more able to mobilize resources to pay for WASH services and the constraints that restrict them from this. Lastly, measurements need to be made on the other essential goods and services that the user pays for and how much they contribute to the income the household earns. If the majority of income already goes to goods and services to provide for the family that this needs to be accounted for than the amount of extra savings are smaller than originally referenced. Once this is understood then the budget for WASH services can be understood and you can begin to understand the baseline amount a user can afford to pay for these services and what income and expenses they are basing this around (ibid).

A basic question that is the core of country case studies is to understand what households spend on WASH as a percentage of their total expenditure? While this question alone can provide viable information to understand what households currently spend and what they could potentially contribute to a new system this question needs to be expanded on to include the other variables related. It is important to determine if the cost should be based on the current reported expenditure of the household or the expenditure required for a minimum level of service? Should the time spent traveling to collect water hold a monetary value that is based on time spent working instead of retrieving water? How does this get quantified when the majority of women and children collecting water work from home or are missing school hours to collect water? In most household expenditure surveys previously collecting data on these issues and solely reporting the baseline questions these often omit capital investments and rehabilitation costs which result in an underestimation of the total WASH cost of services (ibid). Based on a case in Ghana that exemplified these issues when poorest households had to pay the same for WASH services as they paid for housing and twice as much as they pay for education then this is not a viable option for them nor should they reduce their spending on other basic needs such as housing and education to compensate the costs of WASH services. This represents the baseline for lower-income households that might have the income to afford a higher level of WASH services even when they are basin level infrastructure without subsidies in some form then these vulnerable and poorer households cannot ensure the financial access to afford these systems. In addition, these household that is poorer households and more vulnerable are usually those who need safe WASH systems the most due to their reliance of usually inadequate and low-quality eater sources that can be distances away or are suffering the inconvenience of using public latrines or practicing open defecation as a result of their situations (ibid). In addition, when determining the value of a WASH service and the costs households pay for the variables of other basic needs such as housing, electricity, education, food and other necessary payments in addition to the quantified monetary costs of time spent collecting water instead of participating in an income-generating activity it is important to also factor another significant income burden. This is the burden of disease and illness. The costs of traveling to clinics and hospitals, receiving treatment and paying for medicine can accumulate to significant costs and burdens to families when coupled with the number of days they were unable to attend work or school due to their illness. Even in countries where healthcare services might be free or subsidized it is likely that the medication is written out for a pharmacy and these costs can be high depending on the household's income. When these are factored into the costs of WASH services then it is significant to understand the costs of living without safe water compared to the costs of safe water and sanitation services. When surveys collect data understand personally country dependent circumstances then it is clear to understand the need for subsidies that should be in place to help mitigate these costs to ensure communities can afford the basin WASH services that are safe and culturally appropriate (ibid).

Appendix F: Figures (Images and Maps)

Section 3: Map of Loja *Parroquias*

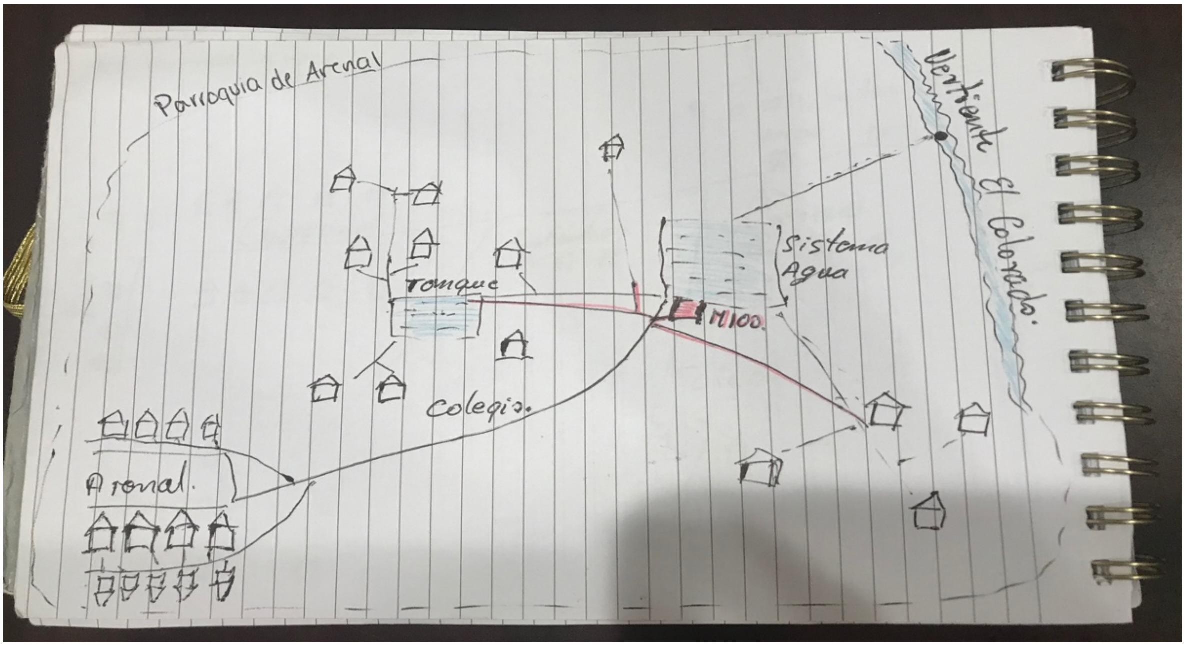


Figure 15: Sketched Map of El Arenal *Parroquia*, El Arenal Community
(Sketcher: A. Prado, July 5, 2019)

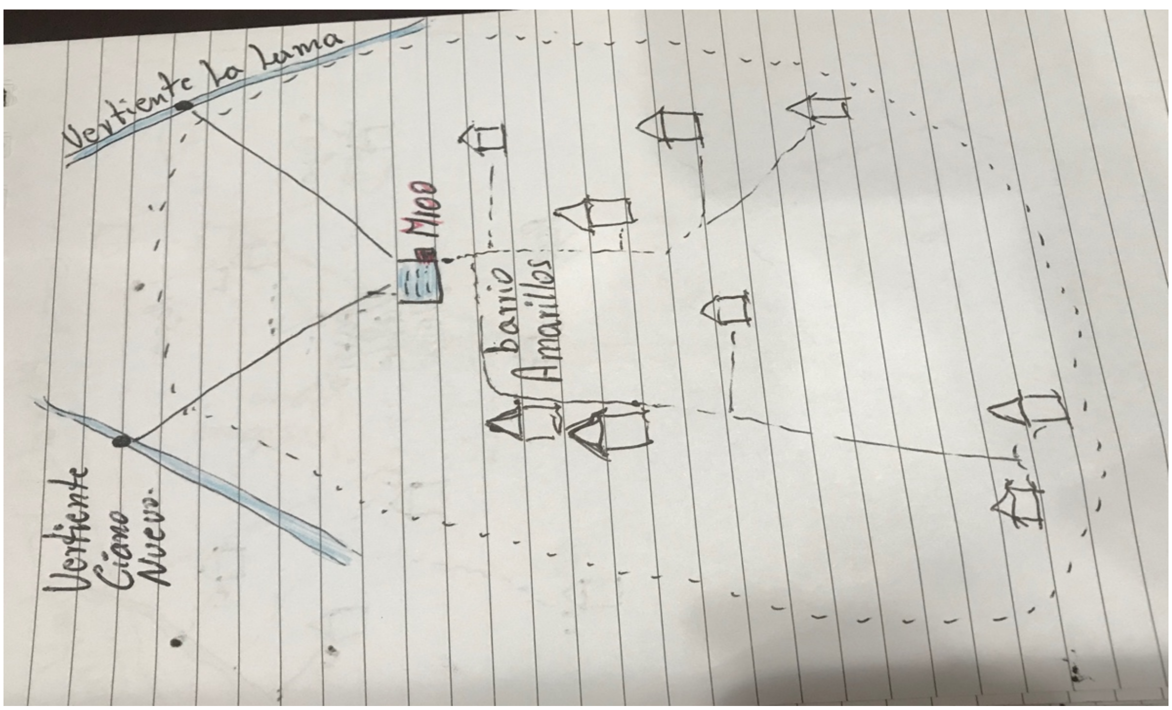


Figure 16: Sketched Map of El Arenal *Parroquia*, Amarillo Community
(Sketcher: A. Prado, July 5, 2019)

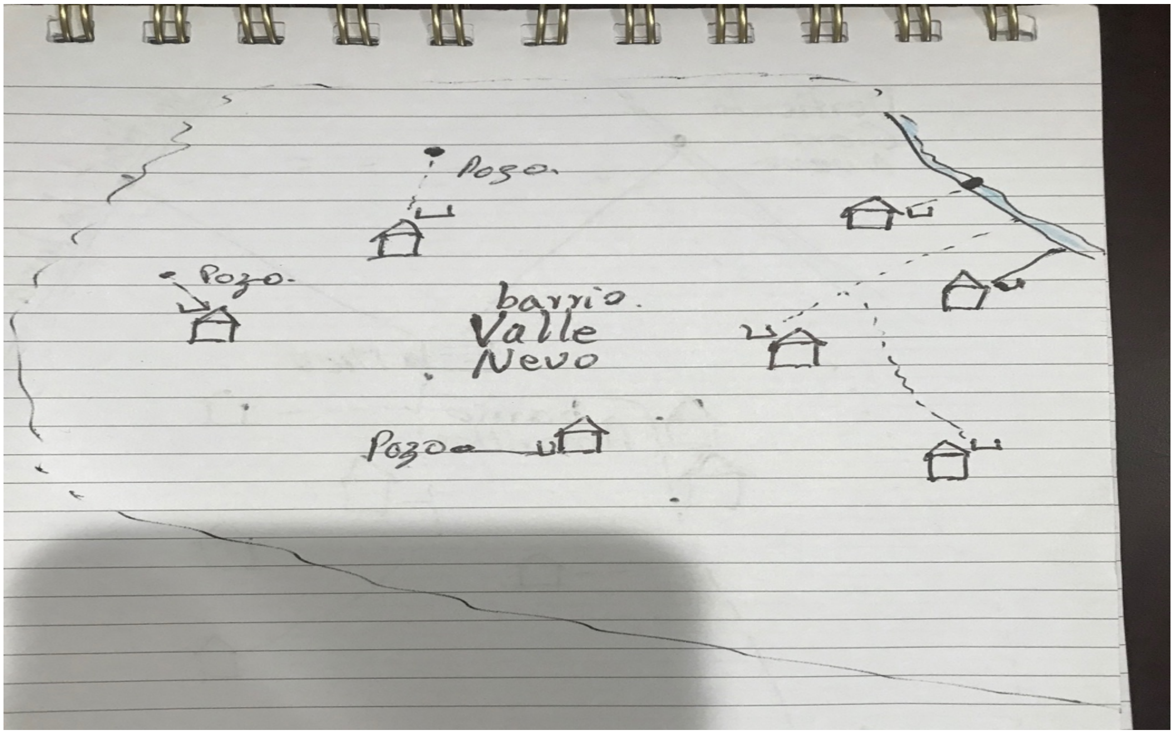


Figure 17: Sketched Map of El Arenal *Parroquia*, Valle Nevo community
(Sketcher: A. Prado, July 5, 2019)

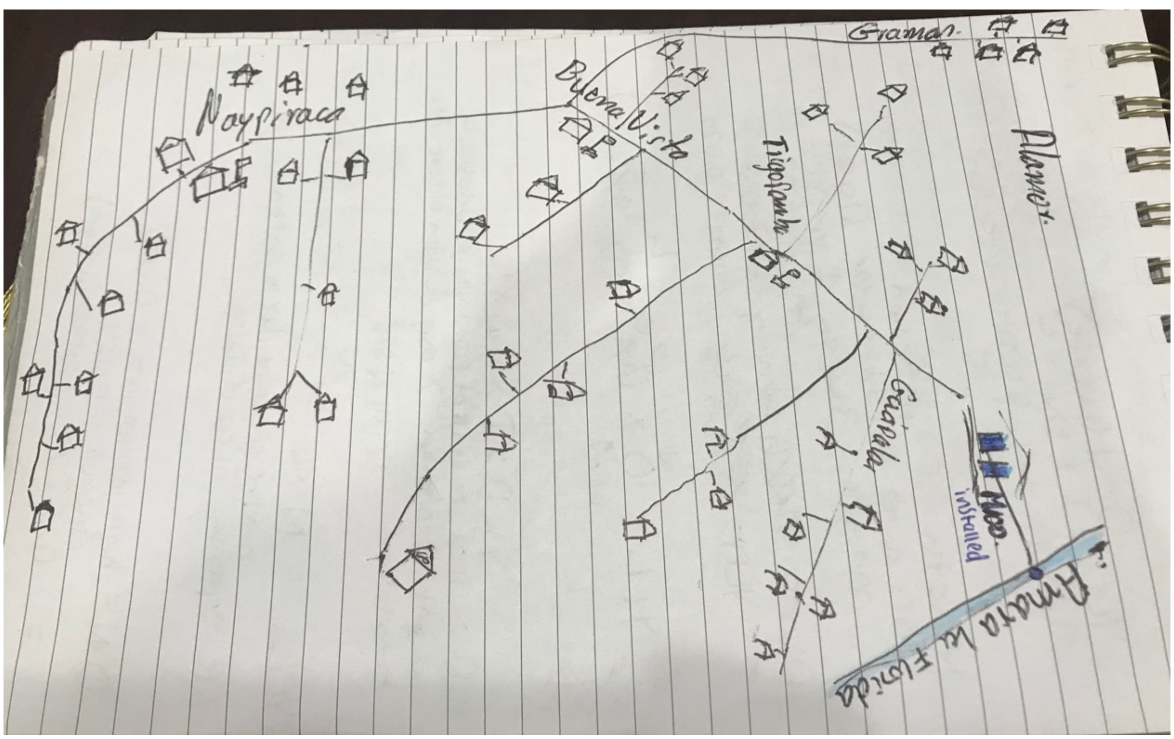


Figure 18: Sketched Map of Alamor *Parroquia*
(Sketcher: A. Prado, July 5, 2019)

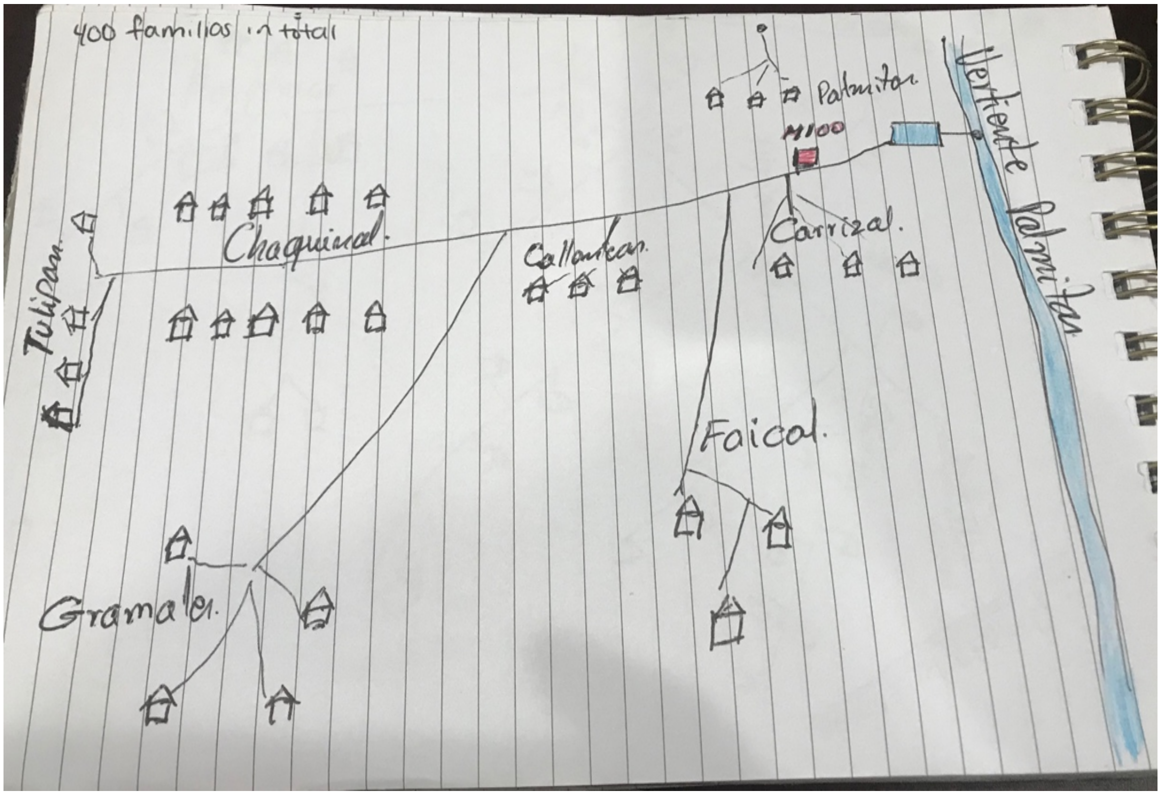


Figure 19: Sketched Map of Chaquinal *Parroquia*
(Sketcher: A. Prado, July 5, 2019)

Section 4: Alta Florencia Rainwater Collection Tanks and Filter Images

Figures 20 and 21: Alta Florencia Rainwater Tank Household Filters
(Photographer: M. Leaska, June 9, 2019)

Figures 22 and 23: Alta Florencia Rainwater Barrel Household Filters
(Photographer: M. Leaska, June 10, 2019)

Section 5: Alta Florencia Images in the Community

Figure 24: Water test conducted in Sacha Ñambi Hostal
(Photographer: M. Leaska, June 7, 2019)


Figure 25: Common Kitchen in Alta Florencia Households
(Photographer: M. Leaska, June 9, 2019)

Figure 26: Alta Florencia Common House Structure
(Photographer: M. Leaska, June 11, 2019)

Figure 27: Alta Florencia: Women Washing Items in the Napo River
(Photographer: M. Leaska, June 10, 2019)

Section 6: Alamor *Parroquia* Safe Water System

Steps of Water Purification System Originating from Point Source in River:
Step 1: Water comes from a mountain stream in Livestock field, beginning filtration uses rocks to avoid debris in the pipes
Step 2: Water travels via a pipe into 4 cement covered containers to than piped to the M100 system
Step 3: Water travels through WaterSteps Disk Filters for initial filtration of contaminants
Step 4: water gets pumped into 2 20,000 cubic meters (c3) tanks to be treated with the M100 system
Step 5: M100 system is used on Tank 1 and takes 4 hours to treat the entire tank and 6 hours to treat tank 2, every day both tanks are treated
Step 6: Safe purified water is tested for 3-5ppm Chlorine levels and piped directly to individual households' access via sinks inside homes
Step 7: Every household has a meter where monthly amounts of water are recorded

Figure 28: Water Collection Point Step One (Photographer: M. Leaska, June 19, 2019)

Figure 29: Water Collection Tanks Step Two

Figure 30: Filtration System Step Three
(Photographer: M. Leaska, June 19, 2019)

Figure 31: Two Water Tanks Step Four

Figure 32: Pipes from Source to Tanks Step Five
(Photographer: M. Leaska, June 19, 2019)

Figure 33: M100 Purification System Step Six

Figure 34: Household Meters for Water Payments Step Seven
(Photographer: M. Leaska, June 19, 2019)

Section 7: Hospital Facilities Interviewed

Figure 35: Chaquinal Hospital
(Photographer: M. Leaska, June 26, 2019)

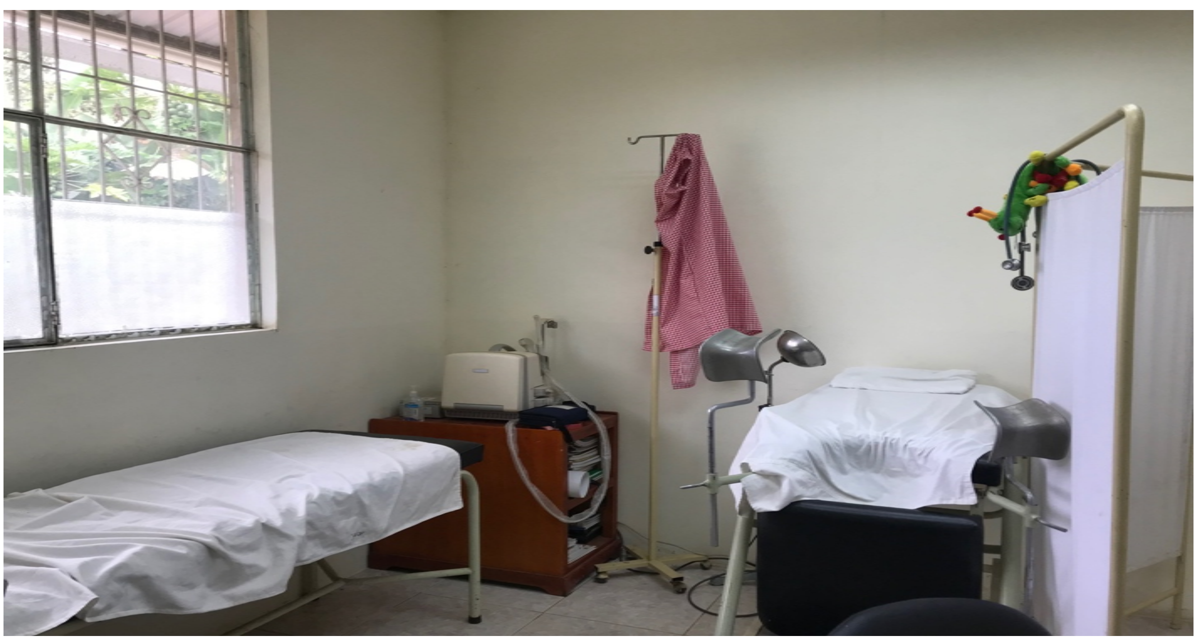
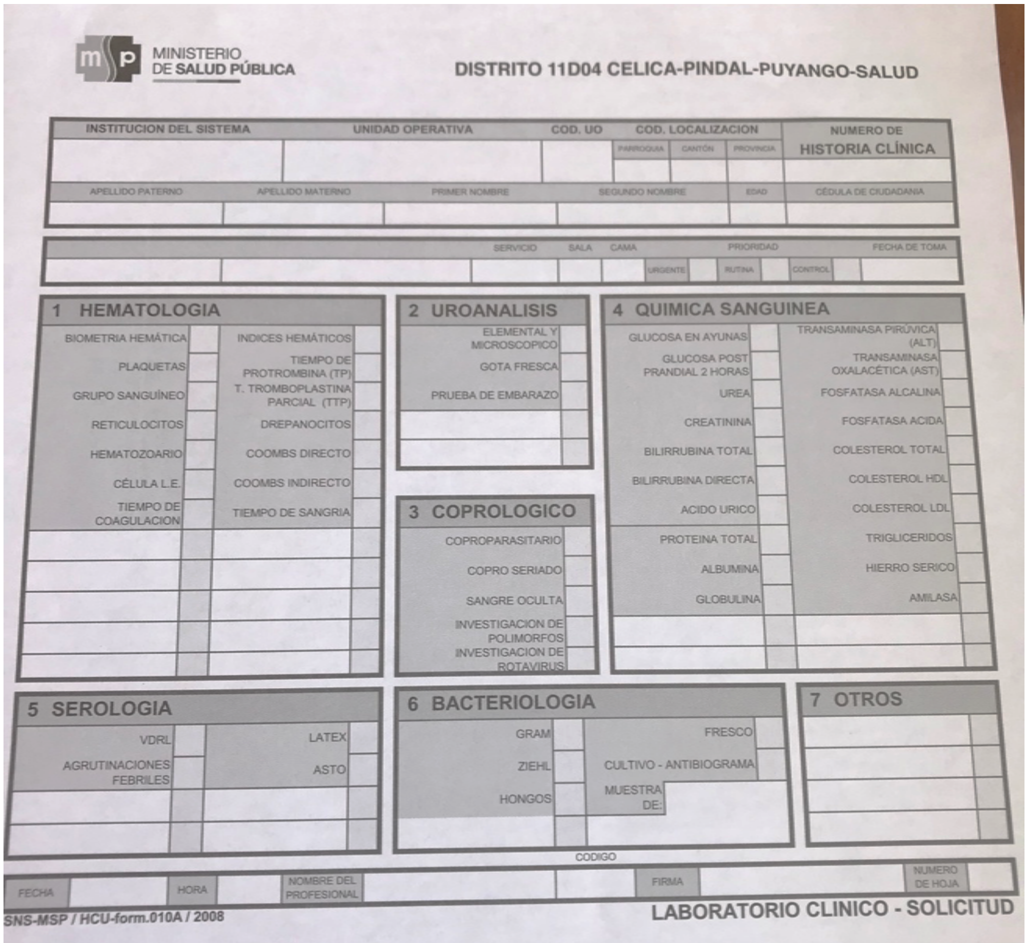


Figure 36: El Arenal Hospital
(Photographer: M. Leaska, June 26, 2019)


MINISTERIO DE SALUD PÚBLICA
DISTRITO 11D04 CELICA-PINDAL-PUYANGO-SALUD

INSTITUCION DEL SISTEMA | UNIDAD OPERATIVA | COD. UO | COD. LOCALIZACION (PARROQUIA, CANTÓN, PROVINCIA) | NUMERO DE HISTORIA CLÍNICA

APELLIDO PATERNO | APELLIDO MATERNO | PRIMER NOMBRE | SEGUNDO NOMBRE | EDAD | CÉDULA DE CIUDADANIA

SERVICIO | SALA | CAMA | PRIORIDAD (URGENTE, RUTINA, CONTROL) | FECHA DE TOMA

1 HEMATOLOGIA
BIOMETRIA HEMÁTICA
PLAQUETAS
GRUPO SANGUÍNEO
RETICULOCITOS
HEMATOZOARIO
CÉLULA L.E.
TIEMPO DE COAGULACION
INDICES HEMÁTICOS
TIEMPO DE PROTROMBINA (TP)
T. TROMBOPLASTINA PARCIAL (TTP)
DREPANOCITOS
COOMBS DIRECTO
COOMBS INDIRECTO
TIEMPO DE SANGRIA

2 UROANALISIS
ELEMENTAL Y MICROSCOPICO
GOTA FRESCA
PRUEBA DE EMBARAZO

3 COPROLOGICO
COPROPARASITARIO
COPRO SERIADO
SANGRE OCULTA
INVESTIGACION DE POLIMORFOS
INVESTIGACION DE ROTAVIRUS

4 QUIMICA SANGUINEA
GLUCOSA EN AYUNAS
GLUCOSA POST PRANDIAL 2 HORAS
UREA
CREATININA
BILIRRUBINA TOTAL
BILIRRUBINA DIRECTA
ACIDO URICO
PROTEINA TOTAL
ALBUMINA
GLOBULINA
TRANSAMINASA PIRÚVICA (ALT)
TRANSAMINASA OXALACÉTICA (AST)
FOSFATASA ALCALINA
FOSFATASA ACIDA
COLESTEROL TOTAL
COLESTEROL HDL
COLESTEROL LDL
TRIGLICERIDOS
HIERRO SERICO
AMILASA

5 SEROLOGIA
VDRL
AGRUTINACIONES FEBRILES
LATEX
ASTO

6 BACTERIOLOGIA
GRAM
ZIEHL
HONGOS
FRESCO
CULTIVO - ANTIBIOGRAMA
MUESTRA DE:

7 OTROS

CODIGO
FECHA | HORA | NOMBRE DEL PROFESIONAL | FIRMA | NUMERO DE HOJA
SNS-MSP / HCU-form.010A / 2008
LABORATORIO CLINICO - SOLICITUD

Figure 37: Sample Stool Test Diagnosis Form
(Photographer: M. Leaska, June 19, 2019)

Section 8: Images from the Field: Chaquinal *Parroquia*

Figure 38: Meeting with Municipality Staff (Photographer: J. Guazha, June 27, 2019)

Figure 39: Interviewee Signing Consent Form

Figure 40: Interview at Household (Photographer: J. Guazha, June 27, 2019)

Figure 41: Latrine with Rainwater Tank

Section 9: Current Water Collection System in Chaquinal *Parroquia*

Steps of Water Collection:
Steps 1 and 2: Water is diverted to cement structure from the mountain stream to be funneled into pipes to holding containers
Steps 3: Two cement holding containers
Step 4: Water travels through pipes and hoses travel underground and above surface to households
--Containers are open-top and from surface sweep with hands algae, insects, and other contaminants were abundant

Figures 42 and 43: Water Collection from Mountain Stream into Funnel Pipe Steps one and two (Photographer: M. Leaska, June 28, 2019)

Figure 44: Water Collection Containers Step Three

Figure 45: Contamination on Surface Water

(Photographer: M. Leaska, June 28, 2019)

Figure 46 and 47: Water Travels through Pipes and Surface Hoses to Households
(Photographer: M. Leaska, June 28, 2019)